THE RELATIONSHIP BETWEEN OPEN SPACE & RESIDENTIAL PROPERTY VALUES IN THE CAPE TOWN METROPOLITAN AREA

By NINSIIMA PRAXIDHA TWEKYE

Research proposal submitted in partial fulfilment of the requirements for the degree Masters in Urban and Regional Planning in the Faculty of Arts and Social Sciences at Stellenbosch University

Supervisor: Danie du Plessis

March 2018

AUTHOR'S DECLARATION

By submitting this assignment electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: 1 November 2017

ABSTRACT

This study aims to determine and assess the relationship between open space and residential property value in the Cape Town Metropolitan area, based on access to open space. The relationships between different open space types and residential property are respectively determined. This is determined at global level using Ordinary Least Squares regression analysis and (more importantly) at local level using Geographically Weighted Regression. Analysis is performed with data aggregated to small area layer level. The main empirical findings indicate that the increase in percentage of recreational areas results in a minor negative effect on property value for the global model (although this is not statically significant). The increase in percentage of parks also results in a minor negative effect on property value. Finally, proximity to protected areas has a positive impact on property value in the global model. For the local model, substantial local variations are revealed, in terms of distribution of local coefficients, and how the distribution can be compared to other socio-economic factors.

Keywords and phrases:

Open space; Hedonic analysis; Geographically Weighted Regression; Local model

OPSOMMING

Die doel van hierdie studie is om die verwantskap tussen toegang tot oopruimte en residensiële eiendomswaarde in die Kaapstad Metropolitaanse gebied te bepaal en te evalueer. Die verhoudings tussen verskillende tipes oop ruimte en residensiële eiendomme word onderskeidelik bepaal. Dit word op globale vlak bepaal deur 'Ordinary Least Squares' regressie-analise asook op plaaslike vlak deur middel van 'Geographically Weighted' regressie. Die ruimtelike eenheid vir die analise is 'Smaal Area Layer' van die sensusdata. Die belangrikste empiriese bevindings dui daarop dat die toename in persentasie ontspanningsgebiede 'n geringe negatiewe invloed op eiendomswaarde vir die globale model tot gevolg het (alhoewel dit nie staties betekenisvol is nie). Die toename in persentasie parke lei ook tot 'n geringe negatiewe uitwerking op eiendomswaarde. Ten slotte het die nabyheid van beskermde gebiede 'n positiewe impak op eiendomswaarde in die globale model. Vir die plaaslike model word aansienlike plaaslike variasies geopenbaar, in terme van die verspreiding van plaaslike koëffisiënte, en hoe die verspreiding vergelyk kan word met ander sosio-ekonomiese faktore.

Trefwoorde en frases: Stedelike Oopruimte; Hedoniese analise; 'Geographically Weighted' Regressie; Plaaslike model; Ruimtelike variasie

ACKNOWLEDGEMENTS

I would like to express my appreciation and thanks to the following people for their assistance with my thesis:

- My father for his constant sacrifices, and continuous encouragement and financial support;
- My supervisor, Danie du Plessis, for the guidance and support throughout my study;
- Mrs Munch for giving guidance on the technical interpretation of regression analysis;
- Theo Pauw, from the Centre for Geographical Analysis, for the technical support with regards to software;
- Coba Kellerman, my peer, who has been there for every step of this academic year.

CONTENTS

TABLES

Page

FIGURES

Page

APPENDICES

Page

ABBREVIATIONS AND ACRONYMS

AICc	Corrected Akaike Information Criterion
CRUISE	Centre for Regional and Urban Innovation and Statistical Exploration
CGA	Centre for Geographical Analysis
CMOSS	Cape Town Metropolitan Open Space System
CTSDF	Cape Town Spatial Development Framework
CV	Cross-validation
D’MOSS	Durban Metropolitan Open Space System
ESRI	Environmental Systems Research Institute
GWR	Geographically Weighted Regression
IDP	Integrated Development Plan
IMEP	Integrated Metropolitan Environmental Policy
JMOSS	Johannesburg Metropolitan Open Space System
OLS	Ordinary Least Squares
RSS	Residual some of squares
SAL	Small area layer
SANBI	South African National Biodiversity Institute
SDF	Spatial Development Framework
TOSF	Tshwane Open Space Framework
WCED	Western Cape Education Department
VIF	Variance Inflation Factor

CHAPTER 1: INTRODUCTION

1.1. BACKGROUND

Open spaces are valued by people since they provide recreational opportunities, natural and scenic views, and also because they lack the negative aspects associated with developed areas (Irwin & Bockstael, 2001; Irwin 2002). An open space is defined as an area that is provided for the benefit and use of the public, and therefore includes parks, golf courses, sports facilities, natural areas, nature reserves, conservation areas, as well as cemeteries (Bolitzer & Netusil, 2000; Green & Argue, 2012).

The importance of the integration of such areas within the urban setting has increased as urban areas continue to develop and grow. Therefore, there is an ongoing trade-off between preserving the open space available, and developing it (Anderson & West, 2006). However, the benefits that open spaces provide has brought them into focus worldwide. In fact, Habitat III, a United Nations Conference on Housing and Sustainable Development, included the promotion of creating and maintaining "safe, inclusive, accessible, green and quality public spaces" in their New Urban Agenda, as a means of tackling inequality (United Nations, General Assembly, 2016). According to the Habitat III issue paper dealing with public space, these spaces that are adequate, well designed and not privatised, lessens segregation (United Nations, General Assembly, 2016). This notion is of relevance to South Africa, a country that still faces extreme spatial segregation in most cities.

It is therefore imperative for planners to consider the integration of open spaces in current and future urban areas. They need to know exactly how open spaces are valued by residents to make the appropriate planning decisions, which could inform planners and developers on providing appropriate and desirable residential areas (Anderson & West, 2006). From an economic viewpoint, open space has a potential influence on residential property values, based on how it is valued by residents (Anderson & West, 2006; Willemse, 2013). Residential property values can therefore give an indication of the importance of integrating open spaces in residential communities.

1.2. RESEARCH PROBLEM STATEMENT & HYPOTHESIS

1.2.1. Research Problem Statement

The relationship between open space and residential property values has been extensively studied in the United States (Anderson & West, 2006; Bolitzer & Netusil, 2000; Bowman, Thompson & Colletti, 2009; Conway et al., 2010; Correll, Lillydahl & Singell, 1978; Crompton, 2005; Irwin & Bockstael, 2001; Irwin, 2002; Geoghegan, 2002), and to a lesser degree in the Netherlands (Koomen et al., 2005; Luttik, 2000), and in Australia (Pearson, Tisdell & Lisle, 2002). From these studies, research shows a general positive relationship between open space and property values.

Crompton (2005) reviewed research using hedonic price modelling, and the study indicates that open space contributes to an increase in property value. Anderson & West (2006) conducted a study to estimate the effects of proximity of residential properties to open space on sales price. This was based on the value residents put on proximity to open space. Residents from denser neighbourhoods, put more value on proximity to open space, than residents from suburbs. Additionally, it was found that depending on neighbourhood density, the impact of open space on property values also depends on income of a household.

Irwin (2002) found that open space surrounding residential properties does influence property value, and that different types of open space will have different influences on the value. For instance, pastureland had a greater impact on residential property value than forests. A study conducted by Bolitzer & Netusil (2000) found that residential properties within half a block of any type of open space, was estimated to have the greatest positive impact on the property value; although this impact was not statistically significant.

In their study, Geoghegan, Lynch & Bucholtz (2003) found that property values increased for residential properties situated adjacent to open space in agricultural areas, in two of the three counties in Maryland, USA, that were assessed. In the third property, values were not affected by the proximity of residential properties to open space, and it is suggested that there being more open space within this county may be the reason why open space is less valued. Lindsey et al. (2004) found that only some greenways have a positive and significant impact on residential property values. They concluded that greenways either positively influence property values, or have no statistically significant influence on them.

Luttik (2000) found that a property overlooking water or open space leads to a considerable increase in property price, and that largest increases in property price were for residential properties with a garden facing water. Pearson, Tisdell & Lisle (2002) found that a view of the headland section of the Noosa National Park (in Queensland, Australia), increased property value by 7%, although being within walking distance to the park has little impact on property value. They also found that the greatest impact on property value is direct distance to the ocean and having a view of the ocean. Furthermore, a negative relationship was found between property value and distance to park, for another park that is considered as not a national park and which is associated with negative characteristics.

In the context of South Africa, only two studies are evident in the available research literature. Cilliers, J. & Cilliers, S. (2015) assessed the impact of the proximity of residential properties to 'green' spaces in relation to their property values, in the city of Potchefstroom, in the North West Province. Their findings showed that green spaces have a negative impact on residential property values at site level, but a positive impact at neighbourhood level. From a conservation planning perspective, Maswime (2006) focused on determining the amenity value of estuaries and the impact of this on property values, in the Cape Floristic Region, in South Africa; and the results from this study indicate a positive impact on residential property values.

Primarily, other studies in South Africa have looked at open space and residential property values as separate subjects. Concerning relatable studies on open space, some studies have focused only on basing the value of open spaces with the qualitative approach of investigating the perceptions of residents of open spaces within and around their neighbourhoods (Landman & Du Toit, 2014; Mashalaba, 2013; Willemse, 2015). In addition, a study conducted by Willemse (2013), determined the proximity of community neighbourhood parks to different income level groups, as a means of assessing 'environmental injustice' between these groups. None of the research on this topic in South Africa use GWR as a hedonic method to assess the relationship between open space and residential property value.

Naturally, South African cities are also developing and growing, especially Cape Town which continues to experience both natural population growth and in-migration (City of Cape Town, 2012a). This puts natural open spaces at risk to residential development projects, where these areas are regarded as potential land to build on. If the benefits of open spaces preservation can be presented in a local context, then developers and planners would be more willing to incorporate them in their plans. One such a benefit is the amenity value of open spaces and its impact on residential property values. Determining the nature of the potential relationship between open space and residential property values, whether positive or negative, within this metropolitan area can aid local planners make decisions that are more informed on future residential development. Also, providing the appropriate, as well as quality and well-maintained open spaces within poorer neighbourhoods could also bring about social, economic, and environmental vitality within these areas; which would lessen the class gap between different types of neighbourhoods. The provision of appropriate public open spaces in future residential developments can therefore help curb the degradation of the natural environment, and indirectly the spatial segregation that is evident in South Africa could be potentially lessened.

This study therefore investigates the following questions:

(i) Is there a relationship between open space and residential property value in the Cape Town metropolitan area?

(ii) Is this a negative and/or positive relationship?

(iii) Does the relationship differ between different open space types?

(iv) What are the implications for spatial planning, in terms of providing open space within neighbourhoods?

1.2.2. Hypothesis

The hypothesis to the problem statement is that there is a positive relationship between access to open space and residential property value through hedonic analysis. Value of property increases, as the provision of open space increases in an area. In addition, the impact on residential property value varies according to the type of open space.

1.3. RESEARCH AIM & OBJECTIVES

1.3.1. Aim

The principal aim of this study is to determine and assess the relationship between open space and residential property value in the Cape Town Metropolitan area. This will be based on access to open space, while distinguishing between types of open space.

1.3.2. Objectives

The aim will be achieved through the following objectives:

1. Determine the relationships between different open space types and residential property value, respectively, based on access to open space.

2. Determine the relationship at global and (more importantly) local level.

1.4. STUDY AREA

The proposed study area falls within the Cape Town Metropolitan area in the Western Cape, South Africa (Figure 1.1). This study area is determined by extent covered primarily by urban development, which is indicated by the orange outline.

Figure 1.1 Map of the study area.

CHAPTER 2: LITERATURE REVIEW

2.1. INTRODUCTION

According to Halprin (1981), our perception of cities is dependent on the landscape of open spaces. This is because these spaces link other parts of a city with their absence, buildings and large infrastructure. They are also the areas in which people come together and partake in activities, such as shopping, walking and playing. Urban open space influences the quality of life of people living in urban areas, since they value open spaces and use them in their daily lives (Natal Town and Regional Planning Commission, 1987; Woolley, 2003).

2.2. WHAT IS URBAN OPEN SPACE?

Urban areas are growing rapidly, due to the increase in populations within these areas. This rapid growth drives a number of problems in the urban environment, such as air pollution, water pollution, waste, noise pollution, the pressure on land for further development, and the degradation of the urban landscape. The quality of life in urban areas may also deteriorate due to growing populations, as social tension and stress increases and mental and physical health is affected, amongst urban residents (Florida Recreation Parks Association, 1975; Woolley, 2003). Open spaces are an important part of the urban environment, as they provide a number of benefits and opportunities for those living in urban areas (Woolley, 2003). Incorporation of urban open spaces could also help curb the above-mentioned issues and they provide an escape from everyday pressures experienced within the urban environment (Florida Recreation Parks Association, 1975).

Internationally, open space has been defined as any undeveloped or mostly undeveloped land that can provide for parks and recreational facilities, conservation of land and other natural resources, or conservation of historic or scenic purposes (Florida Recreation Parks Association, 1975). It has also been defined as an area of land or water in an urban area not covered by buildings or cars and the space and light above the land or water is also included as part of an open space (Woolley, 2003). It can also be viewed as ‘fluid’ so that the city can flow into the open area and vice versa. Some open spaces can accommodate different types of activities which can either be necessary (shopping, going to work, etc.), optional (walking, sitting and standing for leisure), or social (Woolley, 2003). Based on legal ownership or the perception of ownership, open spaces can be defined as public, semi-public, semi-private or private (Florida Recreation Parks Association, 1975; Woolley, 2003). Public open space, which is what this study focuses on, can be defined as open space shared by all individuals.

Urban open spaces were initially used for community meetings that were religious, commercial, or governmental. These spaces catered for a number of different activities, and not for only one type. However, there were some instances where different open spaces were used for specific activities; for example, the market square was distinct from the temple square in early Middle Eastern cities (Crouch, 1981).

In South Africa, open space is usually defined as land that is predominantly undeveloped or unbuilt. However, according to Van Wyk (2012), there is no universal definition provided in the relevant planning documentation. In the Tshwane Open Space Framework (TOSF), open spaces are “areas predominantly free of building that provide ecological, socio-economic and place-making functions at all scales of the [urban] area”; which are either distinguished between soft/green/natural spaces and hard/brown/urban spaces (City of Tshwane, 2005a). Open space has also been defined as any land within and beyond the urban edge that is undeveloped and vegetated (green), and belonging the ecological, social, institutional, heritage, agricultural and prospective open space categories, in the Johannesburg Metropolitan Open Space System (JMOSS) (City of Tshwane, 2005a; Strategic Environmental Focus, 2002; Van Wyk, 2012).

The Durban Metropolitan Open Space System (D’MOSS) also distinguishes between two types of open spaces. The first is identified as areas that can be man-made or legally designated and developed for community use, such as parks, sports fields, streets, town squares, private gardens, etc., which are known as urban open spaces. The second type, known as natural open spaces, is identified as the remaining undisturbed natural and undeveloped areas, such as grasslands, forests, beaches, wetlands, rivers, etc. (City of Tshwane, 2005a; Strategic Environmental Focus, 2002). The Cape Town Metropolitan Open Space System (CMOSS) simply defines open space as “the unbuilt component inside the urban edge that serves a variety of purposes and functions” (City of Tshwane, 2005a; Strategic Environmental Focus, 2002; Van Wyk, 2012). According to the Spatial Planning and Land Use Management Act, 2013 (Act 16 of 2013), open space is the land set aside or that is to be set aside for community use for recreational purposes, regardless of the ownership of the land.

Woolley (2003) extensively discusses the types of open spaces that can be found within urban areas. Table 2.1 lists and briefly describes this typology of urban open spaces. In South Africa, the CSIR Building and Construction Technology (2000) distinguishes between soft open space and hard open space. Hard open spaces are built public space within the built environment, which can be semi-public or completely public, and include mixed-mode streets, pedestrian-oriented streets, squares/plazas, markets, parking areas, and public transport stops and stations. Soft open space refers to unbuilt or ‘green’ areas, which occur naturally in between urban areas.

Table 2.1 Typology of open spaces.

Type	Description	Sub-type	
Domestic urban open spaces	These are characterised by a network of green spaces in which homes are set in, and are treated as an extension of a home. These include gardens, community gardens, courtyards, playgrounds, and even public open space.	Private gardens	
		Community gardens	
		Allotments	
Neighbourhood urban open spaces	These are usually physically further away from homes than domestic urban open spaces, and a person would have to make a conscious decision for a certain purpose to go to one. From a social aspect, people visiting these open spaces are most likely those who live and work in the area.	Parks	
		Playground	
		Playing fields an	
		School playground	
		Streets	
		City farms	
		Incidental spaces and natural green space	
Civic urban open spaces	These are further away from most residential areas, and usually require a person to use alternative transport methods to walking. These open spaces provided greater opportunity for meeting a large variety of people, but also there is less chance of meeting someone you know in these areas, allowing the opportunity for the sense of anonymity.	Commercial	Squares
			Plazas
			Water features
			Office grounds
		Health and education	Hospital grounds
			University campuses
			Courtyards
			Roof gardens
		Transport	Ports and docks
			Transport and waterway corridors
		Recreational	Woodland
			Golf courses
			Cemeteries

(Woolley, 2003)

Parkways, parks, sport fields, play spaces, pristine areas, urban agriculture, and servitudes (covered in vegetation) are all types of soft open spaces.

Francis (1987) distinguishes between traditional and innovative open spaces. Public parks, neighbourhood parks, playgrounds, pedestrian malls, and plazas fall under traditional open spaces. Innovative or newer forms of open space include, community open spaces, neighbourhood open spaces, schoolyards, streets, transit malls, farmers' markets, town trails, vacant/undeveloped open spaces, waterfronts, and found spaces (informal open spaces where social activities take place).

Two other open space types that need to be mentioned and defined are greenbelts and greenways. A greenbelt is a continuous strip of open space made up of water and natural features, which act as an urban boundary, surrounding part or all of a metropolitan or municipal area (Florida Recreation Parks Association, 1975). Greenways are linear corridors of open space following natural features such as rivers or railroads, and occur at a smaller scale than greenbelts (Florida Recreation Parks Association, 1975; Lindsey et al., 2004).

2.3. OPEN SPACE FUNCTION, BENEFITS AND OPPORTUNITIES

Open space must be considered in terms of functionality and be used as a fundamental element in urban planning (Florida Recreation Parks Association, 1975). Also closely related to the functionality of open space, are the benefits and opportunities that they provide in the urban setting. This section provides an overview of these concepts.

2.3.1. Open Space Functions

Florida Recreation Parks Association (1975) looks at open space and the functions that they serve in three different ways. The first is distinguishing between open space *functional types*. 'Utility' open space is a functional open space that caters for the physical needs of people and they supply the areas in which we live, work and move around in. The standards and patterns of people's everyday lives, as well as the relationship people have with the urban environment, are established through the management and structure of these types of open spaces (Florida Recreation Parks Association, 1975).

Another functional type of open space is 'recreational' open space, which refers to open spaces that offer relaxation, a way for people to escape their everyday pressure, and play for people's physical and mental wellbeing. 'Conservation' open spaces are areas demarcated by floodlines, areas of critical natural environment, as well as areas of habitats containing indigenous and endangered species. The last functional open space type discussed is 'multi-use' open space.

This describes open spaces that serve multiple functions, and which cannot be classified solely into any of the other three functional types (Florida Recreation Parks Association, 1975).

Functional characteristics or *elements* that identify, establish, and organise an open space system, by forming smaller systems or networks within the open space systems, are also discussed by Florida Recreation Parks Association (1975). ‘The Edge’ refers to the area or line that gives an open space definition, which establishes boundaries, and joins uses. ‘Linkage’ is the area of open space that provides continuity by connecting open space system elements either linearly or focally. An open space area that serves as a break into urban development, is known as a ‘penetrant’, and acts as an intermediary between the natural landscape and the built surroundings. The ‘focus’ refers to an open space that gives orientation and gives a sense of direction as distance. These types of open spaces are usually landmarks, such as a plaza, but a forest clearing can also be a focal element. ‘Continuity’ describes how the connection and flow of open spaces that are in succession bring about coherence to an open space system (Florida Recreation Parks Association, 1975).

Finally, the Florida Recreation Parks Association (1975) also distinguish between the major *functions* that open spaces perform. Open space that provides natural resources, through production or extraction, for human use and consumption, is known as ‘productive’ open space. These open space areas are related to agricultural and industrial practices. Preserving and protecting these areas is an important consideration when developing an open space system, since they provide sustenance to people and contribute to the economy. ‘Transportation’ open spaces are used as channels or corridors to accommodate movement. They include spaces where utilities, such as pipelines, can pass through. This is an important open space function, because traffic and connectors can be distributed and directed. These types of open spaces can also serve as aesthetic elements along transportation routes (Florida Recreation Parks Association, 1975).

Another type of open space function is ‘urban-shaping’, which refers to urban development occurring on a large scale, where open space can be used to separate or join a multitude of development, and even to prevent development where it is unwanted. Urban-shaping can be used as control element in urban planning to curb urban and suburban growth. Greenbelts and greenways are examples of urban-shaping open spaces, which help control unnecessary provision of utilities and public services, separate towns or communities from each other, and which help preserve the natural environment (Florida Recreation Parks Association, 1975).

‘Urban-structuring’ open space refers to the open spaces within the city boundaries that create the internal shape, form and individuality of the urban area. These open spaces vary in use and size, but are typically surrounded by built development. They essentially act as separators, buffers and focal areas, and serve as a unifying function within the open space system. Open areas reserved for future development are known as ‘urban reserve’ open spaces. Within an ideal open space system, these areas do not replace open spaces serving other important functions, and they provide the necessary area for the growing demand of urban development (Florida Recreation Parks Association, 1975).

There are other functional uses for open spaces that do not fall within the five major functions discussed. Open spaces have been used for water resource management. This includes flood control areas where water is absorbed and stored into reservoirs or artificial lakes, or where the flow of water is channelized and water us drained for urban development use. Open spaces are also utilised for cemeteries and memorial parks. Open spaces surrounding institutions are also present, and they often have multiple uses. Open spaces have also been made available for waste disposal, landfills, and for sewerage treatment facilities (Florida Recreation Parks Association, 1975).

The CSIR Building and Construction Technology (2000) distinguish between social, economic, movement, and political or symbolic functions of hard open spaces. Social functions include play, sports and recreational activities. Cultural entertainment that occur on hard open spaces also fall under the social function. Lingering or resting in hard open spaces is another social activity. Economic functions of hard open spaces include formal/informal trading of street vendors. Outdoor markets and festivals also serve as an economic function, but they also serve as a social function. Economic functions are also performed by public services, civic facilities, and shopping places (CSIR Building and Construction Technology, 2000).

Hard open spaces, such as walkways and sidewalks, intersections, traffic junctions, and also stops and stations, give access to public facilities and transport; serving as movement functions. Parking areas also serve as a movement function. Hard open spaces that serve political or symbolic functions include areas where civic buildings can be constructed and where ceremonial occasions and parades can take place (CSIR Building and Construction Technology, 2000). Soft open spaces have the role of firstly, enabling ecological processes to occur in a sustainable and safe way within the urban environment, and secondly, to accommodate the socio-economic needs of people, and to provide barriers that limit and manage the growth of urban development. These roles or functions are not exclusive to a particular type of open space, since each soft open space should serve as many functions as possible (CSIR Building and Construction Technology, 2000).

2.3.2. Benefits and Opportunities

Three functions of open spaces are identified by Little (1969) as benefits or opportunities that open space can provide for city dwellers. The first is providing recreational opportunities. The environmental amenity, attractive design and aesthetically pleasant landscape of open spaces encompass the second benefit. The last benefit is the conservation, which helps maintain natural process.

Benefits are positive and give advantage to individuals, while opportunities can be defined as an ‘opening offered by circumstances’. Opportunities associated with open spaces include activities, such as walking, relaxing and playing, and these activities can be beneficial to individuals by improving mental or physical health (Woolley, 2003). A number of benefits and opportunities provided by open spaces, with some similar and/or adding to the benefits mentioned by Little (1969) and the open space functions and functional types discussed in the previous section are identified by Woolley (2003).

These benefits and opportunities identified are broadly grouped into the following categories:

Social benefits and opportunities

These opportunities allow individuals to be active in some sort of way or to merely rest/relax. Woolley (2003) discusses topics such as children’s play, passive and active recreation, community involvement and cultural focus, and educational opportunities, as part of social benefits and opportunities. Passive recreational activities are most frequently undertaken in urban open spaces, and can be linked with the “mental health benefits of the restorative opportunities” provided by these areas (Woolley, 2003).

Health benefits and opportunities

Urban open spaces have been associated with both physical and mental health benefits. Physical health benefits are provided by opportunities to exercise in urban open spaces. Restorative effects of nature occurring in urban areas lead to mental health benefits, as mentioned above. Part of these restorative effects of nature include coming into contact with wildlife and also experiencing the aesthetic appeal of urban open spaces (Woolley, 2003).

Environmental benefits and opportunities

Urban open spaces or natural features such as trees can help curb environment and climate issues associated with urban development. Woolley (2003) discusses how tree belts that are adjacent to trees can act as windbreaks to better airflow in urban areas. Open spaces can also help reduce the amount of carbon dioxide polluting the air, as they can allow movement and circulation of polluted air. Trees, and to a lesser extent soil, absorb the carbon dioxide from the air. Some plant species also absorb heavy metals from the air without being negatively affected.

Trees can also help reduce the temperature in urban areas through the transpiration of water. They also absorb and reflect radiation from the sun and provide shade from sunshine, which can be beneficial in areas of hotter climates. Concerning noise pollution, depending on the type of trees and the type of noise, open spaces can help reduce noise pollution, or at least mask the unwanted noise with sounds that are associated with nature. Alternatively, trees can simply create a psychological barrier, making people less aware of noise from the city. Finally, urban open spaces also provide conservation and natural development opportunities for wildlife and indigenous vegetation habitats (Woolley, 2003).

Economic benefits and opportunities

Florida Recreation Parks Association (1975) states that open space has a significant impact on an area’s economy. For example, it was found in some studies that those who participated in recreation activities increased business productivity, which would have possible positive effects on the local economy. In addition, negative income produced through the provision of open space benefits the government, since funds will be saved because the municipal services that would have been needed for development would not be required with the presence of open space (Florida Recreation Parks Association, 1975).

Other economic benefits and opportunities include employment opportunities for people working to maintain the park facilities, and also for planners, engineers, and architects, when new open spaces need to be developed or older ones need to be improved on (Florida Recreation Parks Association, 1975; Woolley, 2003). Administrative and technical staff support all these type of jobs, to ensure efficiency. These opportunities have mostly been provided by the public sector by local authorities, but private firms and trusts have become more involved in the provision, improvement and maintenance of open spaces (Woolley, 2003). In ‘grey’ open spaces such as courtyards and plazas, employment opportunities can be provided for people who sell goods in stalls.

In some instances, new businesses have been set up near park areas, and training and education programmes have started in and around these areas. Another economic opportunity is using open spaces for agricultural purposes, where those living in urban areas grow their own fruit and crops. This is mostly conducted on the fringes of cities of less developed or non-Western countries, and these agricultural areas are pressured and face threat from new urban development of housing and roads within the urban environment (Woolley, 2003).

In Western countries, allotments, community gardens and orchards, and city farms are part of the built environment within the cities. Tourism can also provide economic opportunities and benefits to urban areas. Botanical gardens and civic spaces associated with other well-known attractions, such as museums, draw in tourists from other locations to urban areas (Woolley, 2003).

Finally, the economic benefit based on the impact of open space on property values has been identified, with land developers and researchers finding that property closer to recreational areas attracts more clients and therefore increases the value of property (Crompton, 2000; Florida Recreation Parks Association, 1975). This will be discussed more in depth in the following section of this chapter.

Although, open spaces do provide all these positive outcomes within the urban environment, some open spaces have been associated with crime and drug-related activities. This has to do with the location and the design of an open space (Francis, 1987). Congestion, street parking, litter and vandalism are also negative characteristics of some open spaces. Additionally, it has been found that open spaces that are mostly used for sports activities, which are characteristically large and flat, are less desirable compared to natural open spaces (Crompton, 2000). Crompton (2000) concluded that regardless of the type of park, negative effects will arise if parks are not will designed and maintained, and that some parks can exhibit both positive and negative effects.

Furthermore, a study conducted by Mashalaba (2013), which focused on the use of urban open spaces to revitalise a specific township in Kimberley, South Africa, found that despite the benefits of urban open spaces in urban areas that is evident in literature, open spaces were not regarded as valuable (economically, socially and ecologically) by the local community. It is therefore important to take the potential negative aspect of open spaces into consideration when planning for open space; while also keeping in mind the context of the area in which open space is being provided

2.4. OPEN SPACE & PROPERTY VALUE

Based on empirical evidence it is understood that open spaces have a positive impact on property values. This has lead property developers specifically developing closer to open space features, since the values of the properties located there are often high (Crompton, 2000). Research on early park development in North America and the UK found that the value of property adjacent to parks was higher than property further away from parks. More recent studies conducted in these regions, and the Netherlands, show that property prices can increase with proximity to open space. A five-year study conducted in the City of Worcester, Massachusetts, assessing the values of properties within around one kilometre of four different parks, exhibited the same trend. Additionally, the study found that differences in price increases were also dependent on the type of open space that a property was adjacent to (Woolley, 2003).

Properties close to parks had higher values than those close to open spaces with developed sports facilities (with authors of the study suggesting a more careful design of edges open spaces with developed sports facilities to overcome the negative impact). It is also easier for developers to sell houses that are surrounded by more established and appealing landscape than in unattractive areas. From another study conducted in the Tyne and Wear area of England, areas with the amenity benefits of open spaces tend to be inhabited by middle-class and professional people, and those areas with less amenity benefits from open spaces, are where people of lower socio-economic status live (Woolley, 2003).

Therefore, Woolley (2003) deliberates that there appears to be a relationship between social class and amenity benefits from open spaces, and goes further on to suggest that if lower income areas were provided with the same amenities as in middle income areas, then the value of property in these areas may increase. In this way, spatial segregation could be minimised, through the provision and improvement of open spaces in poorer communities. The focus of this study is to assess whether this economic benefit occurs in the neighbourhoods of Cape Town.

Economists have assessed the economic value of open spaces primarily in two ways. The first method involves using survey/interview techniques, to find out the how much people are willing to pay for the provision of open space, and the second method, hedonic modelling, looks at how open space relates to the value of property (Geoghegan, 2002; Maswime, 2006; McConnell & Walls, 2005). The second method is of interest for this study, since it is most abundant in the available literature. The components and structure of a hedonic model will be discussed in full in Chapter 3 of this paper. The rest of this section discusses the different types of open spaces that have been used in hedonic modelling and the main findings of a few of the studies will presented.

In the study conducted by Anderson & West (2006) neighbourhood parks, special parks, golf courses, cemeteries, lakes, and rivers were the open space types used in the hedonic study. The main finding of their study suggests that the effect of open space on property value is dependent on where a home is located and the characteristics of the neighbourhood it is situated in. According to this, the values of properties in denser areas and close to the CBD are affected significantly more by proximity to open space, than the values of properties in suburban areas. It is suggested that results that focus on neighbourhoods closer to the city should not be used to draw conclusions for suburban areas, and when looking at the open space benefits for average property value in the entire urban area will substantially overestimate or underestimate for values of homes in certain neighbourhoods. These conclusions point to taking the locational context of property into consideration when performing hedonic analysis (Anderson & West, 2006).

A study conducted by Bolitzer & Netusil (2000) found that residential properties within about 6400m^2 of any type of open space, was estimated to have the greatest positive impact on the property value. However, this impact was not statistically significant and it is suggested that more information of the specific features of the open spaces, such as the existence of hiking trails or tennis courts, would provide more detail in such a study. Here, public park, private park, cemetery, and golf course open space types were included in the analysis, similar to the open space types used in the study conducted by Anderson & West (2006).

A study looked at privately owned cropland, pasturelands, forests, and protected land, as well as state-owned non-military open space and military open space (Irwin, 2002). It was found that open space surrounding residential properties does influence property value. Property values are also affected differently by different types of open space. For example, pastureland had a greater impact on residential property value than forests. It is important to note that privately owned cropland, pasturelands, and forests are regarded as potentially developable, and it was found that change from any of these to the other (non-developable) open space types results in additional benefits being estimated (Irwin, 2002).

In the study conducted by Geoghegan, Lynch & Bucholtz (2003) preserved and developable agricultural land, forest, recreational open space, and preserved open space were included as open space types. Private conservation land, golf courses, cemeteries, and county and federal parkland, all fall under the preserved open space category. This study found that property values increased for residential properties situated adjacent to open space in agricultural areas, within two of the three counties chosen as study areas, in Maryland, USA. In the third county, property values were not affected by the proximity of residential properties to open space. The occurrence of more open space within this county could be the reason for this result, since people would perhaps not value open space as highly if they have more and easier access to it. This again stresses the need to consider spatial context in hedonic modelling (Geoghegan, Lynch & Bucholtz, 2003).

Cho, Bowker & Park (2006) include local parks, water bodies (lakes, rivers and streams), and greenways, which have a positive impact on property value. The use of the local GWR model also gives further information about the local variation in the impact of open space, essentially providing locational context within the study. Greenways are also included in a study conducted by Lindsey et al. (2004), which found that only some greenways have a positive and significant impact on residential property values. It was concluded that greenways either positively influence property values, or have no statistically significant influence on them. A positive relationship was found in a study that assessed the effects of greenbelts on property value (Correll, Lillydahl & Singell, 1978). However, although finding was trusted to be true, it is warned that results in the study are exaggerated.

Luttik (2000) included a variety of open space types, distinguishing between open spaces within the residential areas of interest, open spaces bordering the residential areas of interest, and regional open spaces. Open spaces within the residential areas of interest consisted of green strips, parks, canals, and lakes, while open spaces bordering the residential areas consisted of parks and lakes. Woods, lakes, and a ‘diversity of landscape types’ make up the regional open spaces. This study found that a property overlooking water or open space lead to a considerable increase in property price, and those largest increases in property price was for residential properties with a garden that faces open water (Luttik, 2000).

The potential hedonic effects of a national park were specifically assessed by Pearson, Tisdell & Lisle (2002). It was found that a view of the headland section of the park increased property value by 7%. It was also found that being within walking distance to the park has little impact on property value. A negative relationship was found between property value and distance to a non-national park, and this is potentially attributed the park being too well known, leading to problems such as insufficient parking, or attracting ‘unsavoury characters’. The ocean as an open space type was also included in this study and actually direct distance to the ocean or having a view of it had the greatest impact on property.

For the related South African studies, Cilliers, J. & Cilliers, S. (2015) included green open spaces, which they describe as ranging “from recreational green spaces to aesthetic green spaces”. They compared the effects of different types of open space in five different study areas. The first study area is in proximity of a golf course; the second is next to a wetland and an equestrian open space; a natural dam and a playground is located near the third study area; another is next to a river and a non-specific open space; and the last area is adjacent to sports fields. ANOVA (analysis of variance) analysis and Kruskal-Wallis analysis methods were used for the hedonic modelling. The highest impact on property value occurred in the area close to the sports fields. The study area adjacent to the river had the second best impact. The area next the golf course had had the same level of impact as the one next to the wetland and an equestrian open space; leaving the area adjacent to the natural dam and playground with the least impacted property values.

An interviewed based analysis and hedonic analysis to assess the impact of estuaries on residential property value were conducted by Maswime (2006). Interviews were conducted on real-estate agents, which indicated that estuaries have a positive impact on property value. The regression results from the hedonic model also indicate the same finding.

Mashalaba (2013) notes that although there is a general agreement in literature of open spaces increasing property values, this still needs to be applied to "developing countries and cities that do not have a robust property economy dominated by the urban poor". It is therefore suggested that types of open spaces that will be of benefit to different types of communities or neighbourhoods should be investigated. This may be applicable to a country such as South Africa, where the majority of the population is considered poor.

It is important to note that the most often-used open space type used in hedonic modelling is the urban park (Brander & Koetse, 2011). Also, in all these and other studies open space is incorporated based on type, size, percentage, and distance to property into the hedonic model; often with different combinations of these open space measures (McConnell & Walls, 2005). Another important aspect to keep in mind is that the hedonic pricing method does not provide a measure of the total economic benefits of open spaces (Irwin, 2002; Masimwe, 2006).

2.5. URBAN OPEN SPACE PLANNING

The responsibility for the provision of functional open spaces is undertaken by government, who need to accommodate the wishes of the majority of people but at the same time fulfil the individual's needs. Providing, maintaining and conserving open space can be compatible with the development of urban areas, when proper thought goes into planning. Therefore, an open space system should be seen as a crucial element in urban planning and this planning concept would result in taking the value of open space into consideration during urban development (Florida Recreation Parks Association, 1975).

In South Africa open spaces are mostly considered for the space that is left over after the planning of buildings and infrastructure, because provision of open spaces is usually limited by lack of available funds and open spaces are usually the first to face budget cuts, and are not seen as a priority (CSIR Building and Construction Technology, 2000; Nembudani, 1997). They should, however, be properly considered at the initial stages of planning so that they can be designed with a purpose (Natal Town and Regional Planning Commission, 1987). Specifically, in townships, open spaces are neglected, meaning residents of these areas often travel great distances to better maintained recreational areas to enjoy themselves (Nembudani, 1997).

In section 24 of the Constitution of South Africa, it is stated that everyone has the right “to an environment that is not harmful to their health or wellbeing” and “to have the environment protected, for the benefit of present and future generations” by the preventing pollution and ecological degradation, promoting of conservation, and ensuring ecologically sustainable development and the use of natural resources while promoting justifiable economic and social development, through legislation and other policies or plans. Therefore, providing quality open space in urban areas, in all types of neighbourhoods could be considered a constitutional requirement (Constitution of the Republic of South Africa, Act no. 108 of 1996).

In terms of sustainability, South Africa’s planning practices and philosophies before the adoption of the Environmental Conservation Act, 1989 (Act no. 73 of 1989), did not take the environment into account, resulting in large portions of valuable open space being lost, fragmented and damaged (City of Tshwane, 2005a). Subsequent legislation, which deal with the protection of the environment, such as the National Environmental Management Act, 1998 (Act no. 107 of 1998) and its sub-acts, enforce section 24 of the Constitution (National Environmental Management Act, no. 107 of 1998).

For planning related legislation, the Spatial Planning and Land Use Management Act, 2013 (Act no. 16 of 2013) was drafted and adopted, which also makes reference to section 24 of the Constitution and the National Environmental Management Act, 1998 (Act no. 107 of 1998), to promote the protection of environmental rights. In section 50 (1) of this act it is stipulated that applications for residential development also require the provision for parks or open space within their plans (Spatial Planning and Land Use Management, Act no. 16 of 2013).

Typically, the provision of open spaces falls to local government in South Africa. Schedule 5 Part B of the Constitution, lists ‘municipal parks and recreation’ as a local government matter (Constitution of the Republic of South Africa, Act no. 108 of 1996). Chapter 5 of the Local Government: Municipal Systems Act, 2000 (Act no. 32 of 2000) deals with the integrated planning that all municipalities must undertake, by adopting what is known as an integrated development plan (IDP). One of the core components of an IDP is a spatial development framework (SDF), which must provide the basic guidelines for local government’s land use management system (Local Government: Municipal Systems, Act no. 32 of 2000). It is within the SDF of a municipality that planning for open space is considered and implemented.

Municipalities are also guided by the By-laws they draft that accommodate the provision of open space. In Cape Town, the City of Cape Town Municipal Planning By-Law, 2015 and City of Cape Town: Public Parks By-law, 2010, provide additional legal guidelines on the provision, management, and use of open space within the Cape Metropolitan Area.

2.5.1. Metropolitan Open Space Planning in South Africa

City of Cape Town (2012b) defines a metropolitan open space system (MOSS) as an:

> Inter-connected and managed open space network that supports interactions between social, economic and ecological activities, sustaining and enhancing both ecological processes and human settlements: includes natural areas, and active and passive recreation areas such as sports fields and parks, also cemeteries, detention ponds servitudes, river corridors and road reserves to promote interconnection and multi-use.

This section briefly discusses and summarises the MOSS (or open space framework) in terms each of the major metropolitan areas in South Africa, as well as in detail other plans, policies and/or standards that have been specifically used by the City of Cape Town for the provision of open space and for the implementation of its MOSS.

The D'MOSS is the Durban Metropolitan Open Space System (used by the eThekwini Metropolitan Municipality) and was adopted in 1989. It is defined as a network of areas with high biodiversity (Boon, 2017). It uses an ecological approach to open space planning, where the acquisition of areas identified as natural or regenerating is given first priority. Essentially, ensuring the protection and management of all land for the conservation of important biodiversity and supplying ecosystem services, such as clean and adequate water, to the community, are the main, strategic objectives of the D'MOSS (Boon, 2017).

The JMOSS is the MOSS for Johannesburg. It is described as a "decision support and a spatial planning tool that can assist in the promotion of sustainable management of open space" (Strategic Environmental Focus, 2002). Similar to the D'MOSS, the JMOSS focuses on ecological "green" open spaces and does not include hard open spaces. The first phase of JMOSS only involved identifying existing and potential open spaces, by using scientific and ecological principles, which would be incorporated in the open space system. The social-economic aspects are covered in the second phase, where the public participation and ground-truthing is used to refine the MOSS.

The TOSF (Tshwane Open Space Framework) deals with an open space network, which is different to an open space system, as it deals with the overlap between natural and human ecologies. Human ecology has to do with urban processes and human needs, whilst the natural ecology deals with natural processes and systems (City of Tshwane, 2005b). The aim of the

TOSF is to provide an in-depth understanding of the fundamental value of open space within the urban environment, and then to develop a method to create the ideal open space network.

The TOSF consists of three volumes. The first involves the analysis of the current open space available in the metropolitan area, the second reviews the framework's open space vision, policy and plans, and the third volume documents the framework's implementation strategies (City of Tshwane, 2005a).

The CMOSS, the MOSS for the City of Cape Town, developed a vision and criteria for the identification of open space within the City of Cape Town (Marlene Laros & Associates, 2007), and has the following principal aims (City of Cape Town, 2002):

- Develop a definition, vision, criteria, and methodology for identifying and mapping the CMOSS
- Identify the open spaces that should be contained within the CMOSS
- Provide broad guidelines to assist with the management and implementation of the CMOSS

Essentially, three phases were undertaken for the CMOSS. Phase 1 addressed the first aim and involved participation from key stakeholders, as well as the public, through workshops. A draft CMOS map layer was produced based on the methodology developed in phase 1, for phase 2. This represented the first database that was 'inclusive and consistent' of all open space types that were significant to the metropolitan area. However, a 'verification' and 'reconciliation' process of this information was required and involved public participation. Finally, phase 3 involved refining the Management Guidelines Framework of the CMOSS, and the distribution of this draft framework to the relevant officials within the Municipality (City of Cape Town, 2002).

The CMOSS is composed of the following seven open space types (Marlene Laros & Associates, 2007):

1. Ecologically determined space: This describes the biodiversity network and protected areas.
2. Agricultural anchors: These are existing agricultural areas and areas with agricultural potential.
3. 'Blue Parks': These consist of vleis and watercourses, with appropriate buffer zones and edges.

4. Scenic routes
5. Beaches and public edges
6. Multi-purpose urban parks: These serve a number of functions.
7. Socially-determined open space: This includes recreational facilities and facilities that provide public services.

According to Marlene Laros & Associates (2007) the Biodiversity Network, which is part of a strategy by the City of Cape Town to conserve of critical biodiversity areas, will form the "backbone" of CMOSS. The Cape Town Biodiversity Network is "a spatial plan that shows terrestrial and aquatic features that are critical for conserving biodiversity and maintaining ecosystem functioning" (City of Cape Town. (2015b). Ecosystem goods and services provided by open spaces will also serve as structuring elements of the CMOSS (Marlene Laros & Associates, 2007).

The CMOSS is mentioned and implemented in many of the plans and policy documents adopted by the Municipality. Since the City of Cape Town uses these resources to guide them in open space planning, they will be reviewed in the rest of this chapter.

2.5.2. City of Cape Town: Plans, Policies & By-laws

<u>Cape Town Spatial Development Framework</u>

The Cape Town Spatial Development Framework (CTSDF) is a long-term plan used to manage growth and change in the metropolitan area and it is at the top of the hierarchy of spatial plans and policies. It informs districts plans of each of the eight planning districts that make up the City of Cape Town (City of Cape Town, 2012b). One of its key strategies is "to manage urban growth and create a balance between urban development and environmental protection". A sub-strategy relating to open space preservation is that the CTSDF proposes more densification in certain locations to promote sustainability. This will in effect, contain the development extent of the metropolitan area and help protect natural areas at the urban edge. Another sub-strategy is that natural resources, made up of the biodiversity network, aquatic network, and agricultural areas, must be protected and taken into consideration when planning for future development. The CTSDF formulates these strategies into policies and provides policy guidelines to aid in achieving these strategies (City of Cape Town, 2012a). The Biodiversity Network is integrated into the CTSDF, indicating that the CMOSS is a guiding tool within this plan (City of Cape Town, 2015b).

Figure 2.1 is a map produced by the CTSDF (City of Cape Town, 2016a).

The following spatial planning categories, seen in the map, are related to natural assets within the metropolitan area (City of Cape Town, 2012b):

- Core 1: Composed of statutory conservation areas, critical biodiversity areas; conservation priority zones; critical, irreplaceable and restorable biodiversity sites; public conservation areas and private conservation areas.
- Core 2: Composed of ecological corridors; critical ecological support areas; significant coastal and dune protection zones, major river corridors and water bodies excluding waste water treatment works.
- Buffer 1: Composed of rural areas, game and livestock farming areas and other natural vegetation areas that do not form part of the core areas, but are seen as potential biodiversity offsets. Essential utility service infrastructure may be located these areas.
- Buffer 2: Composed of other ecological support areas, transformed game and livestock farming areas, and rural areas that do not form part of the core areas. Essential utility service infrastructure, cemeteries outside the urban edge, and areas zoned as public open space may be located in these areas.
- Intensive agriculture (high potential and unique agricultural land): Composed of agricultural land worthy of long-term protection based on distinctive production, cultural and heritage attributes.
- Intensive agriculture (agricultural areas of significant value): Composed of agricultural areas based on existing use, potential and emerging agricultural use, and food security.

Due to scale, not shown in this map are structuring open space elements such as parks, sport fields and green links, contributing the open space system (City of Cape Town, 2012b).

The Cape Town Bioregional Plan

This is made up of a biodiversity profile for the metropolitan’s bioregion, the Biodiversity Network (a spatial plan), and management guidelines. The purpose is to use these components to inform land-use planning, environmental assessments and authorisations, and natural resources management on matters impacting on biodiversity. It also maps and describes the biodiversity features and characteristics in the region extensively (City of Cape Town, 2015b).

Integrated Metropolitan Environmental Policy

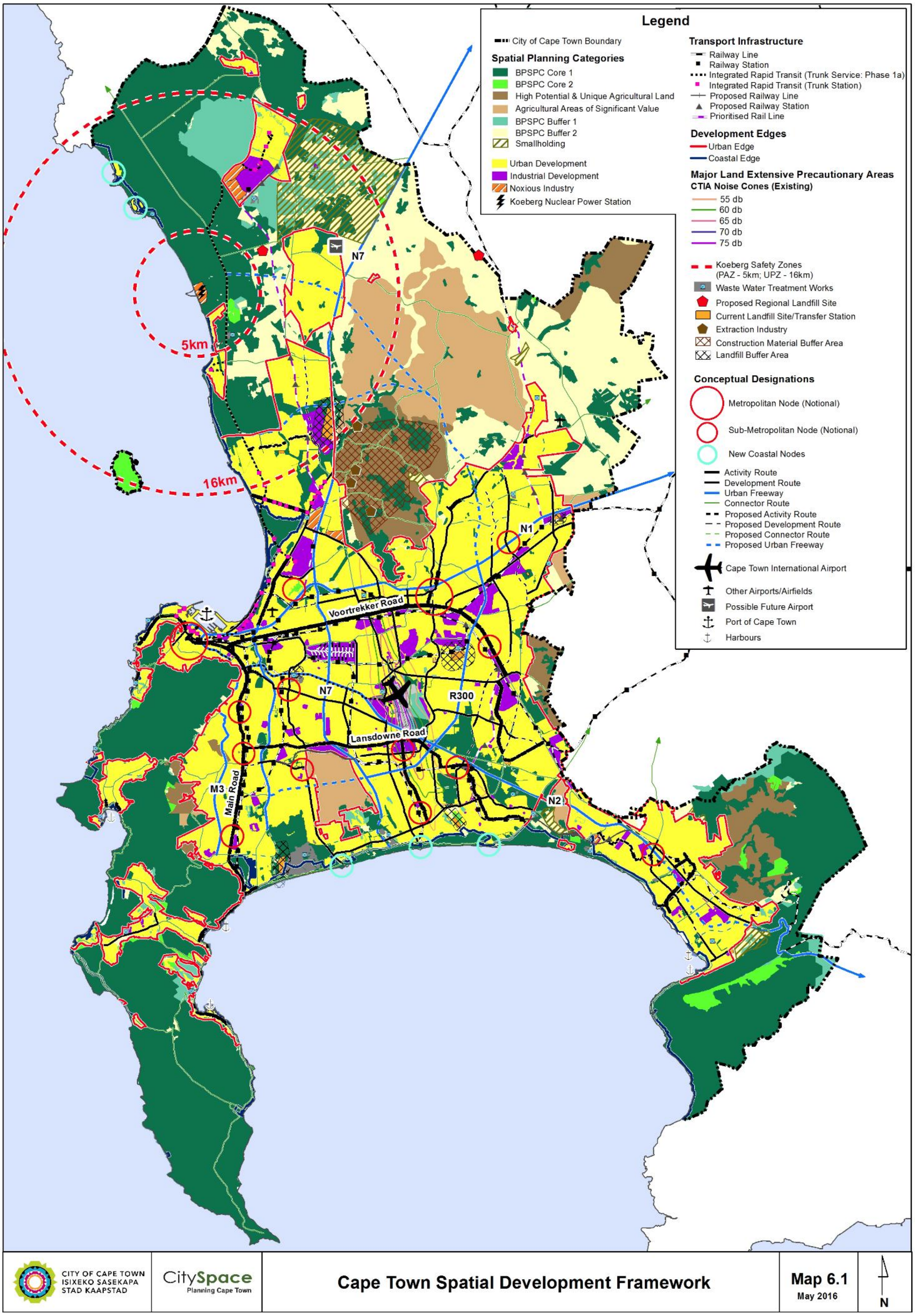


Figure 2.1 Map of Spatial Development Framework (source: City of Cape Town, 2016a).

This policy acts as a framework to guide the City of Cape Town with the environmental management within the metropolitan area. It is heavily guided by the City of Cape Town's 'Year 2020' vision for the environment and uses general policy principles to as tools to reach this goal. Refer to City of Cape Town (2008) for these principles. The Integrated Metropolitan Environmental Policy (IMEP) uses an integrated sectoral approach, promoting sectoral strategies to meet the commitments stipulated in the policy principles (City of Cape Town, 2008).

Parks Development Policy

This document provides broad direction and not detailed instructions, and basic principles include designing for sustainability, designing with communities, designing for use (the needs of the community), designing for integration (favouring clustering of community facilities), and designing to create economic opportunities. Using these principles, the document guides how open space should function and be managed. It aligns with the IDP, SDF, IMEP, and other strategy documents that guide the Municipality in urban planning (City of Cape Town, 2015a).

Sport and Recreational Policy Framework

This policy also enforces Schedule 5 Part B of the Constitution, which lists 'local sports facilities' as a local government matter. It identifies priorities for promoting and expanding access to sport and recreational opportunities, with its main objectives including, the provision of facilities, optimal management of facilities, providing developmental programmes, ensuring engagement with stakeholders. This document indicates how recreational facilities should be provided and managed, and is guided by and aligns with other relevant policy documents, plans, and legislation (City of Cape Town, 2016b).

City of Cape Town Municipal Planning By-Law, 2015

This by-law is essentially the Municipality's development management scheme, which deals with spatial planning matters; specifically, the zoning scheme of the metropolitan area. In section 57 (3) of this by-law, it is stipulated that land for parks or public open spaces must be provided within the land area concerned with development application. It is also stated here that land for parks or public open spaces may be provided somewhere else in the metropolitan area, with the consent of the Municipality (City of Cape Town Municipal Planning By-Law, 2015).

The following are the three open spaces zonings found in this by-law (City of Cape Town Municipal Planning By-Law, 2015):

- Open space zoning 1 (environmental conservation): This primarily deals with environmental conservation use as its primary use.

- Open space zoning 2 (public open space): This zoning deals with both environmental conservation and public open space use.
- Open space zoning 3 (special open space): This deals with environmental conservation, open space, and private road use.

All these open space zonings have associated consent uses, which can be referred to in the by-law (City of Cape Town Municipal Planning By-Law, 2015).

<u>City of Cape Town: Public Parks By-law, 2010</u>

This by-law enforces Schedule 5 Part B of the Constitution, where it lists 'municipal parks and recreation' as a local government matter. This by-law stipulates the uses of public parks within the metropolitan area and the measures put in place in order to manage and maintain them (City of Cape Town: Public Parks By-law, 2010).

As this section shows, there are a number of policies, plans and legislative documents that inform the implementation of the CMOSS in the City of Cape Town. These are interrelated hierarchically and non-hierarchically, therefore the different relevant sectors or departments dealing with open space planning are required to be cohesive.

2.6. HEDONIC ANALYSIS

Hedonic analysis is the proposed approach to assess the relationship between access to open space and property values in this study. It is based on hedonic theory, which has the hypothesis "that goods are valued for their utility-bearing attributes or characteristics" (Rosen, 1974). This quantitative approach has been widely utilised and involves estimating the value/price of a residential property based on its own structural attributes as well as its environmental and neighbourhood attributes (Anderson & West, 2006; Bolitzer & Netusil, 2000; Irwin, 2002; Luttik, 2000). It can also be described as a regression model used to empirically estimate attribute values of a property (Nicholls & Crompton, 2005).

Within the surrounding area, the characteristics of an open space, such as quality of air and aesthetic views, influence the value of the property. This method is however based only on the 'willingness to pay' for the added benefits of open space, by individuals. Therefore, if people are unaware of the benefits they may be receiving from open spaces, then the value of these benefits is not reflected in the value of the property (Lambert 2003).

The model assumes that the property market is in equilibrium and that one market for residential property services is represented in the study area. Based on these assumptions, "the marginal value for a small change in an attribute can be estimated from the hedonic price function" (Bolitzer & Netusil, 2000).

Literature provides various ways of expressing the hedonic price function to assess the relationship between open space and residential property value, but all are more or less made up of the same components. According to Lutzenhiser & Netusil (2001), the hedonic price function is described by the following general equation:

$$P_{\mathrm{i}} = P(S_{\mathrm{i}}, Q_{\mathrm{i}}, N_{\mathrm{i}})$$

Where P_{i} is the value of the i^{th} property, S_{i} is a vector of the property's structural characteristics, Q_{i} is a vector of environmental characteristics, and N_{i} is a vector of neighbourhood characteristics and location (Anderson & West, 2006; Bolitzer & Netusil, 2000; Lutzenhiser & Netusil, 2001).

2.6.1. Issues Associated with Hedonic Analysis

There are a number issues related to hedonic modelling found in literature, some of which are related to the study of open space, and some that apply to all hedonic analyses. For example, including open space that is private and that can be developed into residential use, in a hedonic analysis is problematic. This is because the open space is part of the residential property market and is therefore "subject to the same economic forces that determine a location's residential value" (Irwin & Bockstael, 2001).

This poses two 'identification problems' of land use spillovers that will result in biased coefficient estimates. The first problem is a result of endogenous explanatory variables, where it would need to be determined if the residential value of a property is affected by whether an adjacent property is developed. The second problem is a result of variables that affect property value being spatially correlated, and if open space variables are endogenous in the model, they will be correlated with the error term (Anderson & West, 2006; Irwin & Bockstael, 2001; Irwin, 2002; Geoghegan, Lynch & Bucholtz, 2003). According to Cho, Poudyal & Roberts (2008), most open space, apart from public or preserved open space, will be endogenous to the hedonic model. Therefore, it is important to exclude these types of open space from the analysis and only use areas that will be permanently preserved as open space (Anderson & West, 2006).

Issues can also occur due to model specification, which is determined mainly by theoretical guidance, regarding the expected signs of certain coefficients, the availability of data and the deductions made about the relevant independent variables to be used (Irwin, 2002). Cho, Bowker & Park (2006) mention claims of issues with model specification resulting from omitted independent variables, collinearity between variables, and spatial dependency (spatial correlation) between variables.

Determining the functional form of the hedonic price function is viewed as a significant issue due to the weak or little theoretical guidance on the restrictions on functional form; and therefore choice of functional form is usually determined by empirical evidence (Anderson & West, 2006; Hui et al., 2007; Irwin, 2002; McConnell & Walls, 2005; Meese & Wallace, 1991; Pavlov, 2000; Saphores & Li, 2012). Linear, quadratic, log–log, log–linear, semilog, and Box–Cox functional transformations have been used in hedonic analyses (McConnell & Walls, 2005).

The most effective and commonly used method to determine an appropriate functional form, is comparing the goodness-of-fit criterion from alternative functional forms, for example log–log compared to semilog, and choosing the best fitting model (Hui et al., 2007; Irwin, 2002). Otherwise, a Box–Cox transformation or flexible functional form approaches can be used to generalise the model, but these require great effort since many more coefficients need to be estimated (Anderson & West, 2006; Irwin, 2002; McConnell & Walls, 2005; Meese & Wallace, 1991). However, when accounting for omitted variables a linear version of the Box–Cox transformation is more robust than other functional forms, because bias occurs more in complicated models than the simpler linear model (Irwin, 2002; McConnell & Walls, 2005).

According to Cho, Poudyal & Roberts (2008), in previous studies it was found that distance, property value, and area variables gave better results in a log functional form than in a linear functional form. This is due to the log transformation being able to capture the 'declining effect' of these variables. This functional form also corrects for heteroscedasticity (Cho, Poudyal & Roberts, 2008; Sirmans, Macpherson & Zietz, 2005). Pavlov (2000), used the log form of property values for the dependent variable, to address the property values being highly skewed. Anderson & West (2006) used a log–log functional form in their study, after a graphical inspection of the relationship between the dependent and independent variables. Bowman, Thompson & Colletti (2009) used a semi-log transformation for their analysis. Irwin (2002) compared results from log–log, semilog, and simple linear functional forms and the log–log model performed better, and the semilog model second best.

An obvious issue regarding the hedonic analysis approach is that all relevant characteristics cannot be observed or measured (McConnell & Walls, 2005; Pavlov, 2005). This is often due to lack of necessary data. Unfortunately, hedonic analysis is affected by omitted variables (Pavlov, 2000). Omitted variables may be spatially correlated, and therefore result in spatial autocorrelation in the error terms. In addition, estimators that are biased and inconsistent can be a result of omitted variables that are correlated with explanatory variables included in the analysis (Anderson & West, 2006; McConnell & Walls, 2005; Netusil, 2005; Saphores & Li, 2012). One solution for this is to incorporate location into the hedonic analysis, where spatial varying coefficients can be estimated (Pavlov, 2000). Spatial locally weighted regression methods are able to do this. According to Koomen et al. (2005), location of property is in fact an important exploratory variable for property value.

Furthermore, when dealing with spatial data, spatial autocorrelation needs to be accounted for within the hedonic analysis, because if not, this could lead to biased estimators and inferences that are misleading (Geoghegan, Lynch & Bucholtz, 2003; Koomen et al., 2005; McConnell & Walls, 2005; Saphores & Li, 2012). According to McConnell & Walls (2005), apart from omitting variables, spatial autocorrelation can be a result of measurement error, where for instance the scale at which the variable is measured, does not correspond to the spatial scale that the error was generated. Multicollinearity is also problematic in hedonic analysis and often occurs because properties from the same areas exhibit similar characteristics and these characteristics are likely to be correlated (Irwin, 2002).

Finally, traditional hedonic models also make the assumption that property values are constant across a housing market (Cho, Poudyal & Roberts, 2008). This can result in issues related to the geographic extent of the housing market, and it is argued by some that separate hedonic price functions should be used for separate geographic areas (Irwin, 2002; Geoghegan, Wainger & Bockstael, 1997). This is only possible, however, if each area is represented by its own housing market, which do not have any significant overlap with each other and act as interrelated submarkets (Cho, Bowker & Park, 2006; Irwin, 2002; McConnell & Walls, 2005).

2.6.2. Variables

Sirmans, Macpherson & Zietz (2005) identify a number characteristics of property used for hedonic analysis. Age of house is the most frequent characteristic. This is followed by square footage (structure area), which is also sometimes used in its log form. Lot size is another characteristic that has also been frequently used, as well as in its log form. The number of bathrooms, rooms, bedrooms and storeys, and the existence of fireplaces, garages, decks, pools, basements, air-conditioning, and a brick exterior is also listed. Distance variables have also been used. Time-on-the-market and time trends have also been used as variables in a few studies. There are number of other characteristics mentioned by Sirmans, Macpherson & Zietz (2005), but the ones mentioned above are considered as the top twenty characteristics.

Table 2.2 Variables found in literature.

	VARIABLE NAME/DESCRIPTION	SOURCE
Dependent variable	Property value	Acharya & Bennet (2001); Anderson & West (2006); Bolitzer & Netusil (2000); Brander & Koetse (2011); Correll, Lillydahl & Singell (1978); Geoghegan, Lynch & Bucholtz (2003); Hicks & Queen (2016); Hui et al. (2007); Lewis, Bohlen & Wilson (2008); Lutzenhiser & Netusil (2001); Maswime (2006); Nicholls & Crompton (2005); Saphores & Li (2012); Standiford & Scott (2001); Troy & Grove (2008); Tse & Love (2000)
Structural variables	Lot/property area	Acharya & Bennet (2001); Anderson & West (2006); Bolitzer & Netusil (2000); Correll, Lillydahl & Singell (1978); Geoghegan, Lynch & Bucholtz (2003); Irwin & Bockstael (2001); Irwin (2002); Lewis, Bohlen & Wilson (2008); Lindsey et al. (2004); Lutzenhiser & Netusil (2001); Netusil (2005); Nicholls & Crompton (2005); Pearson, Tisdell & Lisle (2002); Saphores & Li (2012); Standiford & Scott (2001); Towe (2009); Troy & Grove (2008)
	Structure area	Acharya & Bennet (2001); Bolitzer & Netusil (2000); Correll, Lillydahl & Singell (1978); Geoghegan, Lynch & Bucholtz (2003); Hicks & Queen (2016); Irwin & Bockstael (2001); Irwin (2002); Lewis, Bohlen & Wilson (2008); Lindsey et al. (2004); Lutzenhiser & Netusil (2001); Netusil (2005); Nicholls & Crompton (2005); Saphores & Li (2012); Standiford & Scott (2001); Troy & Grove (2008); Tse & Love (2000); Tyrväinen (1997)
	Number of rooms/bedrooms	Correll, Lillydahl & Singell (1978); Hicks & Queen (2016); Hui et al. (2007); Koomen et al. (2005); Lewis, Bohlen & Wilson (2008); Lindsey et al. (2004); Nicholls & Crompton (2005); Saphores & Li (2012); Standiford & Scott (2001); Tyrväinen (1997)
	Number of bathrooms	Acharya & Bennet (2001); Anderson & West (2006); Bolitzer & Netusil (2000); Hicks & Queen (2016); Hui et al. (2007); Irwin & Bockstael (2001); Irwin & Bockstael (2001); Irwin (2002); Lewis, Bohlen & Wilson (2008); Lindsey et al. (2004); Lutzenhiser & Netusil (2001); Nicholls & Crompton (2005); Saphores & Li (2012); Troy & Grove (2008)
	Number of garages	Acharya & Bennet (2001); Lindsey et al. (2004); Nicholls & Crompton (2005); Netusil (2005); Tse & Love (2000)
	Age of house	Acharya & Bennet (2001); Anderson & West (2006); Bolitzer & Netusil (2000); Correll, Lillydahl & Singell (1978); Geoghegan, Lynch & Bucholtz (2003); Irwin & Bockstael (2001); Irwin (2002); Koomen et al. (2005); Lewis, Bohlen & Wilson (2008); Lindsey et al. (2004); Lutzenhiser & Netusil (2001); Netusil (2005); Nicholls & Crompton (2005); Saphores & Li (2012); Towe (2009); Troy & Grove (2008); Tse & Love (2000); Tyrväinen (1997)
	Grade/quality of house	Irwin & Bockstael (2001); Irwin (2002); Towe (2009); Troy & Grove (2008); Tyrväinen (1997)

Continued overleaf

Table 2.2 continued

	VARIABLE NAME/DESCRIPTION	SOURCE
	Number of storeys	Geoghegan, Lynch & Bucholtz (2003); Hui et al. (2007); Lindsey et al. (2004); Nicholls & Crompton (2005); Netusil (2005); Towe (2009)
	Existence of fireplace	Acharya & Bennet (2001); Anderson & West (2006); Lewis, Bohlen & Wilson (2008); Lutzenhiser & Netusil (2001); Nicholls & Crompton (2005)
	Existence of swimming pool	Acharya & Bennet (2001); Nicholls & Crompton (2005); Saphores & Li (2012); Standiford & Scott (2001)
Environmental variables	Area of open space	Anderson & West (2006); Maswime (2006); Towe (2009)
	View of open space	Hui et al. (2007); Koomen et al. (2005); Nicholls & Crompton (2005); Pearson, Tisdell & Lisle (2002); Tse & Love (2000)
	Percentage of open space (within a given radius)	Acharya & Bennet (2001); Geoghegan, Lynch & Bucholtz (2003); Lewis, Bohlen & Wilson (2008); Irwin & Bockstael (2001); Irwin (2002); Netusil (2005)
	Number of open space	Bolitzer & Netusil (2000)
	Population density	Acharya & Bennet (2001); Anderson & West (2006); Brander & Koetse (2011); Irwin & Bockstael (2001); Irwin (2002); Saphores & Li (2012)
	Density of residential land use	Irwin (2002); Netusil (2005); Tyrväinen (1997)
Neighbourhood & location variables	Distance to open space	Acharya & Bennet (2001); Anderson & West (2006); Brander & Koetse (2011); Correll, Lillydahl & Singell (1978); Hicks & Queen (2016); Hui et al. (2007); Koomen et al. (2005); Lewis, Bohlen & Wilson (2008); Lindsey et al. (2004); Nicholls & Crompton (2005); Pearson, Tisdell & Lisle (2002); Saphores & Li (2012); Standiford & Scott (2001); Troy & Grove (2008); Tse & Love (2000); Tyrväinen (1997)
	Distance to CBD	Anderson & West (2006); Bolitzer & Netusil (2000); Correll, Lillydahl & Singell (1978); Irwin & Bockstael (2001); Irwin (2002); Maswime (2006); Troy & Grove (2008); Tyrväinen (1997)
	Distance to nearest public transport station	Hui et al. (2007); Koomen et al. (2005); Tyrväinen (1997)
	Distance to school	Maswime (2006); Nicholls & Crompton (2005); Tyrväinen (1997)
	Distance to shops/shopping centre	Maswime (2006); Pearson, Tisdell & Lisle (2002); Tse & Love (2000); Tyrväinen (1997)
	Distance to airport	Hicks & Queen (2016); Irwin (2002); Tyrväinen (1997)
	Distance to nearest highway entry/exit	Acharya & Bennet (2001); Hicks & Queen (2016); Koomen et al. (2005); Maswime (2006); Nicholls & Crompton (2005); Saphores & Li (2012); Troy & Grove (2008)

Continued overleaf

Table 2.2 continued

VARIABLE NAME/DESCRIPTION	SOURCE
Average household income	Anderson & West (2006); Geoghegan, Lynch & Bucholtz (2003); Irwin & Bockstael (2001); Irwin (2002); Koomen et al. (2005); Lewis, Bohlen & Wilson (2008); Lindsey et al. (2004); Saphores & Li (2012); Troy & Grove (2008)
Number of reported serious crimes per 1000 people	Acharya & Bennet (2001); Anderson & West (2006); Saphores & Li (2012); Troy & Grove (2008)
Percentage of population younger than 18 years old	Anderson & West (2006); Saphores & Li (2012)
Percentage of population aged 65 years and older	Anderson & West (2006); Saphores & Li (2012)
Percentage of population of certain or different ethnicities	Acharya & Bennet (2001); Irwin & Bockstael (2001); Irwin (2002); Koomen et al. (2005); Lindsey et al. (2004); Saphores & Li (2012)
Percentage of high school graduates/education beyond high school	Acharya & Bennet (2001); Irwin & Bockstael (2001); Troy & Grove (2008)
Proportion of households below the poverty line or Proximity to slums (informal areas)	Gupta, Mythili & Hegde (2009); Lewis, Bohlen & Wilson (2008)

Since the inclusion of all relevant exploratory variables is important, relevant literature was consulted to identify variables that have been most frequently used. After consulting a number of studies, the most relevant variables, based on their occurrence, were identified and are summarised in Table 2.2. Some of these correspond to the top twenty identified by Sirmans, Macpherson & Zietz (2005), while others do not. Since it is the dependent variable in all housing price hedonic studies, property value (or price) was found in all the referred studies.

The common structural characteristics of a property are listed as property or lot area, the area of the house structure, the number of rooms or bedrooms in the house, number of bathrooms, number of garages, the age of the house, the grade or quality of the house, number of storeys, the existence open space, percentage of open space within a given radius, number of open space, population density, and density of residential land use, were identified as the common environmental characteristics/variables.

The locational variables include distances to certain amenities and services, such as open space, the CBD, the nearest public transport station, schools, shops or shopping centres, the airport, and the nearest highway entry or exit. Average household income, number of reported crimes, the percentage of population younger than 18 years old, the percentage of population 65 years old and older, percentage of population of certain or different ethnicities, the percentage of high school graduates/education beyond high school, the proportion of households below the poverty line or proximity to slums (informal areas), are included as neighbourhood characteristics. In fact, the proportion of households below the poverty line and proximity to slums (informal areas) variables, each only occur in one study (of all the studies consulted), but were included in the table since a majority of people reside in informal settlements or are below the poverty line within South Africa; and they could be potential relevant variables.

The names or descriptions of the variables in the table, are merely general and encompassing terms for the variables found in the different studies, which are also presented in different measurement units. These variables will guide the exploratory variables that will be used in this study, depending on their relevance to and the data available for the study area.

2.7. GEOGRAPHICALLY WEIGHTED REGRESSION

2.7.1. Regression Analysis

Linear regression has been used in geography related fields for quite some time, to investigate the relationships between spatial observations (Brunsdon, Fotheringham & Charlton, 1998). It involves studying or modelling the causal relationship between a dependent variable and a set of one or more independent, explanatory variables. This method assumes that there is a linear relationship between the dependent and independent variables, but there are also other methods that can be used to test a functional relationship between variables, which all fall under the umbrella term of 'regression analysis' (Charlton & Fotheringham, 2009b; Rogerson, 2001).

However, these traditional methods do not take location of observations into account when analysing relationships. This is because they were developed to deal with aspatial data, which contain only attribute information, and many of them are not applicable to spatial data, which contain both attribute and locational information (Brunsdon, Fotheringham & Charlton, 1998; Fotheringham, Brunsdon & Charlton, 2002).

Tobler's first law of geography, which states that "everything is related to everything else, but near things are more related than distant things" (Tobler, 1970), refers to how spatial features are spatially dependent on each other; in other words, how they are spatially autocorrelated (Beale et al., 2010). This means that measurements of observations that are geographically close together are usually similar, whereas measurements of observations that are more geographically apart are usually dissimilar (Beale et al., 2010).

2.7.2. Spatial Regression

Traditional (global) spatial regression models were developed to take spatial dependency of spatial data into account. Although they are not seen as local models, they do recognise the local 'nature' of spatial data, in that they can identify whether the model's residuals exhibit spatial autocorrelation (Charlton & Fotheringham, 2009a; Fotheringham, Brunsdon & Charlton, 2002; LeSage, 1997; Yu, 2006). Furthermore, Beale et al. (2010) state that errors (which residuals are estimated from) in standard regression models are expected to be spatially dependent, and it is therefore important to consider this when modelling spatial data.

Since global regression methods use a summarised single value for the entire area of study, global spatial analysis and spatial modelling can be misleading. Local statistics, however are better suited for analysis on spatial data since each value for each feature or observation is derived. Additionally, local statistical methods are useful in assessing spatial processes, as they also may vary over space (Fotheringham, Brunsdon & Charlton, 2002; Huang, Wu & Barry, 2010; Leung, Mei, & Zhang, 2000). To reiterate, spatial data (as well as spatial processes) may be spatially dependent, but they also exhibit spatial non-stationarity; meaning that their values, and therefore also the regression coefficients, vary when looking at different locations (Cho, Bowker & Park, 2006; Yu, 2006). Therefore, standard spatial regression models are also not entirely suitable for assessing the relationships between spatial data, since local relationships are measured with a global statistic and the output of these models are a set of global parameter estimates (Fotheringham, Brunsdon & Charlton, 2002).

2.7.3. Local GWR Method

GWR, is a locally weighted regression method that allows relationships that vary over space between variables to be investigated, by estimating local instead of global parameters. This is achieved by estimating and mapping parameters for each regression point by using the location of the observations in space (Brunsdon, Fotheringham & Charlton, 1996; Cho, et al., 2009; Fotheringham, Charlton & Brunsdon, 1998; Wheeler & Páez, 2009). The method uses distance weighted sub-samples of the data to generate locally linear regression estimates for every point in space (LeSage, 2001).

A global spatial regression model can be written with the following function:

$$y_i = \beta_0 + \sum_k \beta_k x_{ik} + \varepsilon_i$$

The GWR model expands on the standard regression method for using spatial data by allowing parameters to be estimated locally (Huang, Wu & Barry, 2010; Yu, 2006), so that the model is written as:

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i) x_{ik} + \varepsilon_i$$

Where y_i is the dependent variable at location i; x_{ik} is the value of the kth independent variable at location i; (u_i, v_i) represents the coordinates of the ith point; $\beta_0(u_i, v_i)$ is the intercept value at location i; $\beta_k(u_i, v_i)$ is the local regression coefficient for the kth independent variable at location i; and ε_i is the random error term location i. The GWR equation recognises the potential existence of spatial variations in relationships and provides a way in which they can be measured (Cho, Bowker & Park, 2006; Cho, et al., 2009; Fotheringham, Brunsdon & Charlton, 2002; Huang, Wu & Barry, 2010; Wheeler & Tiefelsdorf, 2005; Wheeler, 2007).

When considering the equation as a hedonic function, y_i is the value of property at location i; and x_{ik} are the variables of the structural, neighbourhood, and location characteristics k (Cho, Bowker & Park, 2006; Cho & Roberts, 2007; Cho, et al., 2009)

Using a locally least square method, GWR assigns weight to an observation based on its proximity to location i, when estimating each variable's coefficient at location i. For the calibration of the model, it is assumed that the observations near i have a more of an influence in the estimation of the $\beta_k(u_i, v_i)$ parameters than those farther from i. The estimation of parameters $\beta_k(u_i, v_i)$ is given by the following:

$$\hat{\beta}(u_i, v_i) = [X^T W(u_i, v_i) X]^{-1} X^T W(u_i, v_i) Y$$

Where $\hat{\beta}$ represents an estimate of β; X is a vector of the independent variables; Y is a vector of the dependent variable; and $W(u_i, v_i)$ is an $n \times n$ matrix whose diagonal elements represent the geographical weighting of observations for observation i, and the off-diagonal elements are zero. The weight matrix is calculated for each point i where parameters are estimated (Cho, Bowker & Park, 2006; Cho, Poudyal & Roberts, 2008; Fotheringham, Brunsdon & Charlton, 2002; Huang, Wu & Barry, 2010; Yu, 2006).

The weights matrix is specified as a local kernel function, which "models a distance decay effect from the n calibration locations to the prediction location i". The most commonly used spatial weighting function is the Gaussian function:

$$W_{ij} = \exp\left(-\frac{d_{ij}^2}{b^2}\right)$$

where b is the bandwidth, which generates 'a decay of influence with distance' and d_{ij} is the distance between i and j; characterising a fixed spatial kernel function(Cho, Bowker & Park, 2006; Fotheringham, Brunsdon & Charlton, 2002; Saphores & Li, 2012). Another commonly used function is the bi-square function:

$$w_{ij} = \begin{cases} \left[1 - \left(\frac{d_{ij}}{b}\right)^2\right]^2 & \text{if } d_{ij} < b, \\ 0 & \text{otherwise,} \end{cases}$$

This is a near-Gaussian function that provides a weight of zero when the distance is finite and is described as an adaptive kernel function, since b adapts from observation to observation, as it represents the maximum distances between observation i and its nearest neighbours (Cho, Bowker & Park, 2006; Farber & Páez (2007); Fotheringham, Brunsdon & Charlton, 2002; Wheeler and Tiefelsdorf, 2005).

2.7.4. Issues Associated with GWR

GWR has a number of issues that need to be kept in mind or addressed, when being used. For instance, fixed kernels have problems related to them, such as being larger than needed where data are denser, leading to estimates derived from these types of kernels to be affected by (increasing) bias; since changes in relationships at smaller distances may be missed. Estimates derived with kernels that are too large become very close to those derived by a global model. Fixed kernels that are smaller where data are scarce will result in high standard errors of the estimated coefficients (Brunsdon, Fotheringham & Charlton, 1998; Fotheringham, Brunsdon & Charlton, 2002; Huang, Wu & Barry, 2010).

A fixed kernel is only suitable when data points are relatively evenly spaced out throughout the study (Charlton & Fotheringham, 2009b). Adaptive kernels vary spatially, becoming smaller where data are denser and larger where density of data is sparser, and they therefore address the problems of fixed kernels (Fotheringham, Brunsdon & Charlton, 2002). Also, to reduce computational cost when dealing with very large datasets, Brunsdon, Fotheringham & Charlton (1996) suggest using the adaptive bi-square weighting kernel.

According to Charlton & Fotheringham (2009b), as long as the kernel is Gaussian-like it can be used, and in actuality, the choice of bandwidth is more significant than the shape of kernel, when it comes to influencing the fit of the model. The weights derived from the model 'approach unity' and the local GWR model becomes more like the global OLS model, as the bandwidth increases. Since the choice of the bandwidth is important in GWR, cross-validation (CV) is a method suggested in literature to determine optimal bandwidth, as it is an effective way to address the bias-standard error or bias-variance trade-off (Brunsdon, Fotheringham & Charlton, 1998; Cho, Bowker & Park, 2006; Farber & Páez, 2007; Fotheringham, Brunsdon & Charlton, 2002; Huang, Wu & Barry, 2010; Wheeler, 2007; Wheeler & Páez, 2009).

This trade-off is an important issue in GWR, because the method is unlikely to provide an unbiased estimate of $\beta(u_i, v_i)$ at location i, since coefficients vary continuously over space and there will be a different value of β for each observation; but regression requires that β be the same value for all the observations. To address this bias, only values of observations close to location i are considered to estimate $\beta(u_i, v_i)$. This will however, increase the standard error for $\hat{\beta}(u_i, v_i)$, the closer to i that $\beta(u_i, v_i)$ is estimated (since the sample size for the estimate has been reduced). In essence, the variance becomes large but the bias becomes small when the estimate is too close to location i, and the other way around when it is too far (Fotheringham, Charlton & Brunsdon, 1998; Fotheringham, Brunsdon & Charlton, 2002).

The bias-variance trade-off, which is a result of coefficient heterogeneity and the size of bandwidth, is related to one of the major issues associated with the GWR method; which is the occurrence of extreme coefficients (Farber & Páez, 2007). According to Farber & Páez (2007), GWR is likely to estimate extreme coefficients, as well as provide sign reversals of coefficients. In their study, Cho et al. (2009) found that although GWR derives extreme coefficients irrespective of the resolution of the data or the type of kernel function, GWR tends to generate extreme coefficients for sparser datasets; extreme coefficients are more likely to be derived from polygon data representing aggregated values; and extreme coefficients are more likely to be derived using fixed kernels than using adaptive kernels.

GWR is supposed to explore coefficient variability but extremely varying coefficients may be an indication of over-fitting in the model, the occurrence of multicollinearity, or some other problem that needs to be addressed (Farber & Páez, 2007). Extreme coefficients may not only be caused by spatially varying coefficients, but also by resolution and distribution of the data, and/or "misspecification related to geography captured by the coefficients". It is therefore advised to be cautious when interpreting results from GWR, as they may be affected by extreme coefficients, which should be identified and removed (Cho et al, 2009).

Potential multicollinearity is another major issue associated with GWR, as it can produce statistical artifacts in regression coefficients (Cho et al, 2009; Wheeler, 2007). In their study, Wheeler and Tiefelsdorf (2005), found that multicollinearity effects were stronger in the GWR model than in global regression models. This means that any interpretation of GWR parameter estimates are potentially invalidated by model coefficients, and if not addressed the derived conclusions can be misleading. According to Cho, Poudyal & Roberts (2008), multicollinearity may be a major issue if the correlation coefficient between two variables is more than 0.8. They used variance inflation factors to detect multicollinearity in their study.

Another issue to be aware of is spatial error dependence (Cho et al, 2009), also known as spatial autocorrelation. According to Leung, Mei & Zhang (2000), "spatial autocorrelation can invalidate the standard assumption of homoscedasticity of the disturbances and mislead the results of statistical inference". This means that the variance of error terms is potentially not consistent, which is problematic. Testing for spatial autocorrelation in the error terms when using the GWR model is therefore important. Moran's *I* and Greary's *c* were used by Leung, Mei & Zhang (2000) as a measure of spatial autocorrelation. However, these are global statistics and it is therefore suggested to use the local indicators of spatial association (LISA) method to measure spatial autocorrelation of residuals at a local level. Fotheringham, Brunsdon & Charlton (2002), also calculated Moran's *I*, as well as used a local spatial autoregressive model to measure spatial autocorrelation of the residuals in their study.

LeSage (2001) suggests a Bayesian approach to GWR to address issues identified, such as extreme coefficients (outliers) and non-constant variance over space. The method also adds a parameter smoothing relationship to the GWR, to restrict the estimates based on spatial relationships. Additionally, this approach addressed the lack of sample independence resulting in potentially invalid measures of dispersion in the GWR method, by producing Bayesian estimates using the Gibbs sampler.

2.8. LITERATURE REVIEW CONCLUSION

This chapter essentially ties the theory on open space and the theory on the hedonic modelling and GWR methods, from the available literature. Open space is defined and classified and open space functions are discussed, as well as the benefits and opportunities that open spaces offer. The relationship between open space and property value is also discussed in detail. The implementation of urban open space planning is assessed, and a closer look is taken in the Cape Town context through the discussion of the City’s plans, policies and by-laws. Finally, an in depth literature study on hedonic modelling and GWR is done, to determine the suitability of these methods to assess the relationship between open space and property value.

CHAPTER 3: METHODOLOGY

The proposed methodology for this study follows an empirical research approach based on the objectives stated in Section 1.3.2. The research will be conducted in a quantitative manner, since regression methods will be used for the analysis of spatial data. Figure 3.1 illustrates the five components of the research process. The first component includes the formulation of the study's problem statement, aim and objective. It is also in this component that the study area is determined.

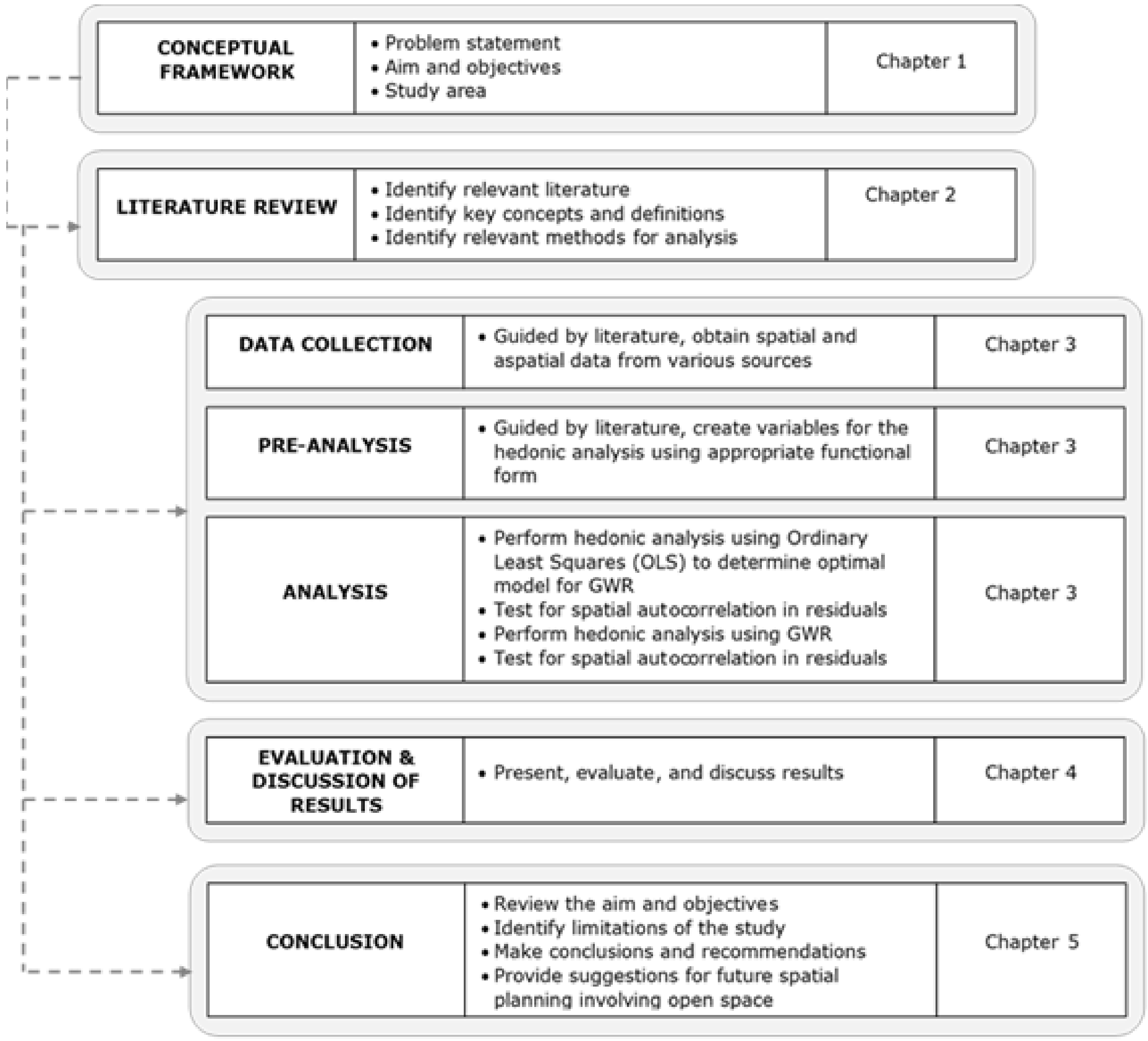


Figure 3.1 Research design

The second component involved an extensive review on literature relating to open space, by referring to both international and local literature. Key concepts and definitions are identified, planning policies related to open space are reviewed, and an overview of the relationship between open space and property value is discussed. The hedonic and GWR methods were also reviewed and presented in the second chapter. The consequent components are also guided by the available literature.

The third component includes an overview of the data collected, the steps taken to derive the relevant variables for the hedonic model, as well as the steps taken for the hedonic analysis; which are discussed in Section 3.2 of this chapter. Presentation, evaluation and interpretation of the results is undertaken in the fourth component, which is essentially Chapter 4.

In the final and concluding component, Chapter 5, the study's aim and objectives are reviewed, the limitations experienced in the study are discussed, as well as recommendations for future work on this topic. Suggestions for future spatial planning involving open space are also provided.

3.1. EMPIRICAL ANALYSIS

3.1.1. Data Collection & Input

The proposed data sets for this study are summarised in Table 3.1. The data were obtained with guidance from literature, based on the characteristics or variables typically used in hedonic modelling. The general valuation roll conducted by the City of Cape Town provides the property value, based on the market value, for each property within the study area. This data was provided in an excel spreadsheet, by the Centre for Regional and Urban Innovation and Statistical Exploration (CRUISE) at Stellenbosch University. A more current data set containing valuations from 2015 is available, but the 2012 dataset was chosen because it is closer to date with 2011 census (the most current census of South Africa) which is required to analyse some of the neighbourhood characteristics in the hedonic price function, and it also includes property characteristics.

This data set provides the dependent variable (property values), as well as property structural characteristics such as area of property, number of bedrooms, and number of bathrooms that can be used in the study. Unfortunately, although age of a house is the most used characteristic used in hedonic modelling, data describing this was not available in the valuation roll. Spatial data for the residential properties in valuation roll was also sourced, which enabled linking this data set to the aspatial data from the spreadsheet.

The dependent variable and the relevant independent variables (described by structural characteristics) were aggregated to small area entities, by mean value. Small areas are spatially represented by the small area layer (SAL) of census 2011, which consists of enumeration areas

Table 3.1 Data sets used.

TYPE	DATE	DESCRIPTION	SOURCE
General valuation roll	2012	Excel spreadsheet consisting of property value based on the market value of a property, as well as property structural characteristics; of which area of property, number of bedrooms, and number of bathrooms will be used	City of Cape Town
Land parcel polygon shapefile		Spatial data containing land parcels (residential properties) in the valuation roll	City of Cape Town
Census data	2011	National census data, including variables such as population density, average household income, and population of different ethnic groups (all collected at small area layer level)	Statistics South Africa
Small area layer polygon shapefile		Spatial data containing all small areas within the study area	Statistics South Africa)
Informal settlements/areas polygon shapefile	2010	Informal settlements/areas within the study area	CRUISE, Stellenbosch University
CBD point shapefile	2017	A single digitised point of the proposed location of the CBD within the study area	Self digitised.
Primary road line shapefile	2014	Main/primary roads within the study area	Openstreetmaps web portal
Highway entry/exit point shapefile	2014	Digitised at entry/exit points of motorways/highways	Motorways/highways – Openstreetmaps web portal
Train station point shapefile	2017	Digitised points along railway lines shapefile (created in 2014), with aid of a georeferenced image from SA transport	Railway lines – Openstreetmaps web portal; Reference image for points – SA transport
Bus stop point shapefile	2014 & 2016	Golden arrow bus stops and MyCiti bus stops	Code4SA web portal; City of Cape Town open data portal
Schools point shapefile	2017	Generated from x and y coordinates	WCED Find-a-School website
Shopping centre point shapefile	2010	Major shopping centres within the study area	CRUISE, Stellenbosch University

Continued overleaf

Table 3.1 continued

TYPE	DATE	DESCRIPTION	SOURCE
Open space shapefiles	2016	Community parks, district parks, greenbelts, undeveloped public open space, and sports grounds	City of Cape Town open data portal
	2006	Recreational areas, parks and golf courses/driving ranges derived from land use maps	CGA, Stellenbosch University
	2009	All types of open space (publicly and privately owned)	CGA, Stellenbosch University
	2011	Protected areas	CGA, Stellenbosch University (Primary source: SANBI)

(the smallest geographical unit used for census in South Africa) combined into small areas (Statistics South Africa, n.d.; Statistics South Africa, 2017). Population density, average household income, and population of different ethnic groups were derived from census 2011, also at SAL level. All other variables would be aggregated and/or assigned to this spatial level of accuracy.

There are two reasons for conducting the analysis at SAL level, the first being that there are simply too many residential properties within the study area, which would have led to high computational cost and redundancy in the model; since the difference between characteristics of properties in very close proximity would be hardly distinguishable. This gives way to the option of sampling properties within the area of study, which is the second issue. The sample set would have had to be representative of the data by having a sufficient number of properties in low, middle, and high income areas to be statistically viable, making it too complex. Therefore, by aggregating individual properties to SAL level, computational cost is decreased and sampling is avoided.

A shapefile of informal settlements was also sourced, to create a variable that could potentially impact the value of property negatively. Open space data was obtained from a number of sources. Community parks, district parks, greenbelts, undeveloped public open space, and sports grounds were obtained from the City of Cape Town open data portal. All of these are polygon shapefiles, except for sports grounds, which is a point data set. Recreational areas, parks and golf courses/driving ranges were derived from land use maps, sourced from the Centre for Geographical Analysis (CGA) at Stellenbosch University.

Another data set sourced from CGA, is one that contains all types of open space (publicly and privately owned). Finally, a shapefile of the protected areas created by the South African National Biodiversity Institute (SANBI) was also sourced from the CGA. These open space data sets were later assessed and combined/modified to create the final open space variables that will be used in the analysis.

There were a number of data sets that had to be created or derived from other sources, due to lack of data. A point shapefile, containing as single point that represents the "location" of the CBD was created. Primary or main roads were derived from a roads line shapefile, sourced from the Openstreetmaps web portal. Entry/exit points to motorways or highways were digitised on these roads from the same roads shapefile. A train station data set was created by digitising points along a railway lines shapefile (sourced from the Openstreetmaps web portal), with aid of a georeferenced image from SA transport. Bus stop data was created by combing point shapefile data for Golden Arrow) bus stops (sourced from Code4SA web portal with MyCiti bus stops (sourced from City of Cape Town open data portal). A schools point shapefile was created by using the x and y coordinates for all schools within the study area, which were obtained from Western Cape Education Department (WCED) Fine-a-School website. A shopping centre point shapefile was sourced from CRUISE, Stellenbosch University but had to be "cleaned" since in some instances there were multiple points representing one shopping centre.

Although crime data was obtained, it was not used because the police station boundaries are at a much coarser scale than the SAL data. This means scaling issues would occur if the crime statistics for a police station, which includes a number of small areas within its boundaries, where assigned to each of the small areas; essentially producing an ecological fallacy.

These datasets did not generate all variables listed in Section 3.1.1.2, but based on the literature it is assumed that a sufficient number of variables will be available for the study. However, the potential effects of omitted variables will be kept in mind and during the analysis. Also, cognisance of the accuracy or quality of data must also be taken, as this might also affect results, especially data from open source databases and data that was self-digitised or -created.

3.1.2. Software & Tools

ArcMap 10.4.1, an ArcGIS software application developed by the Environmental Systems Research Institute (ESRI), was used for data input and creation, and also to generate the variables required for the hedonic analysis. The generation of these variables is discussed in Section 3.2.3.

GWR was introduced by Fotheringham, Brunsdon & Charlton (2002), who are associated with the National Centre for Geocomputation at Maynooth University, Ireland. The National Centre for Geocomputation aided ESRI in the development the GWR Tool in the ArcGIS (Geographically Weighted Modelling, 2017). The GWR tool in ArcMap was meant to be used for the hedonic analysis, but unforeseen complications associated with potential multicollinearity or other unknown reasons prevented this. Therefore, GWR was performed using R version 3.4.2, which is used for statistical computing, using the spgwr package.

However, before using GWR the data was first explored using IBM SPSS Statistics 25 software and the global Ordinary Least Squares (OLS) tool in ArcMap was used to determine the best model for the analysis using the GWR tool (Charlton, & Fotheringham, 2009a; ESRI, 2016a). The Spatial Autocorrelation (Moran's I) tool will be utilised to assess whether the residuals from the OLS analysis, exhibit spatial autocorrelation. After assessing the results from the OLS and determining the absence of spatial autocorrelation within the data, the hedonic analysis will be performed using the GWR tool.

3.1.3. Variables

The variables in Table 3.2 were determined for the hedonic analysis after deriving them from the available data and after assessing the relationships between independent variables and the dependent variable in different functional forms, during initial exploration of variables for OLS. The dependent variable *Ln_Rm2*, which is the Rand per m^2 (in natural log form), was derived by first dividing property value by property area for each property and aggregating the residential

properties to SAL level, using the mean of total Rand per m^2 values in each small area. It was decided to make the dependent variable Rand per m^2 rather than Rand because it offers a more logical unit of comparison. For example, bigger houses would tend to be of more value than smaller houses, therefore houses of similar size with very different Rand per m^2 values can then be attributed to other property and neighbourhood characteristics. A second dependent variable *Ln_Rm2dext* was also derived the same way as *Ln_Rm2*, but using the area of the dwelling extent rather than of the whole property. This was done for comparison purposes. The mean values for untransformed Rand per m^2 (of property extent) and Rand per m^2 (of dwelling extent) variables are R2 085.42 per m^2 and R7 091.80 per m^2.

Table 3.2 Derived variables for hedonic analysis.

	Variable	Description	Mean of R per m^2 (untransformed)
Dependent variables	***Ln_Rm2***	Rand per m^2 (property area)	2 085.42
	Ln_Rm2dext	Rand per m^2 (dwelling area)	7 091.80
Structural variables	***Mean_bed***	Number of rooms/bedrooms	
	Mean_bath	Number of bathrooms	
Environmental variables	***Bus_km2***	Number of bus stops within small area per km^2	
	Schlwa_km2	Number of schools within small area and adjacent small areas per km^2	
	Shopwa_km2	Number of shopping centres within small area and adjacent small areas per km^2	
	Ln_Popdens	Population density (Population per km^2)	
	Recwa_perc	Percentage of recreational areas within a small area and adjacent small areas	
	Parkwa_pe	Percentage of parks within a small area and adjacent small areas	
Neighbourhood & location variables	***Dist2PA***	Distance to protected areas	
	Ln_CBD	Distance to CBD in km (log form)	
	Dist2Infor	Distance to nearest informal housing in km	
	Dist2Train	Distance to nearest train station in km	
	Dis2Rdbuff	Distance to 500m buffer of primary roads or entries/exits to motorways	
	HHI	Degree of ethnic homogeneity/heterogeneity (Black African, Coloured, Indian or Asian, White, and Other)	
	Ln_AvgHHIn	Average household income in Rands	

The independent structural variables *Mean_bed* and *Mean_bath* were also derived by aggregating the residential properties to SAL level and using the mean of total number of bedrooms per property and mean of total number of bathrooms per property, in each small area. The environmental variables are made up of *Bus_km2*, *Schlwa_km2*, *Shopwa_km2*, *Ln_Popdens*, *Recwa_perc*, and *Parkwa_pe*. *Bus_km2* represents the number of bus stops within each small area per km2. *Schlwa_km2* represents the number of schools within a small area and its adjacent small areas per km2. The reason of adding the number of schools from neighbouring small areas, is that there were not many schools found in each small area. *Shopwa_km2* was derived the same way as *Schlwa_km2*, but for shopping centres. Population density is represented by the independent variable *Ln_Popdens*, which was derived by dividing the total population within small area by its area in km^2 and converting that to log form.

From the open space data that as collected four types of open space variables were derived, the first *Recwa_perc* represents the percentage of the area of recreational areas/facilities within each small area and adjacent small areas. Recreational areas include all grounds used for recreational purposes, including sports grounds or fields (excluding those of schools), tennis courts, swimming pools, and golf courses. *Parkwa_pe* was also similarly calculated for parks, which includes community/neighbourhood and district parks.

Dist2PA, a location variable, represents the distance of each small area to protected areas, which are natural areas under conservation. These three open space categories were chosen since this study focuses on open space that is public, green/soft and used for recreational or conservation purposes. Therefore, greenbelts and undeveloped public open spaces are not included in the study. For *Ln_CBD*, the distance from each small area to the CBD was calculated and then converted into log form. Distance to the nearest informal settlement is represented by *Dist2Infor* and distance to the nearest train station is represented by *Dist2Train*, for each small area. Primary roads have far more entries/exits than motorways/highways, and that why is the roads themselves were used. Motorways/highways on the other hand, are not as easily accessible, hence the use of nodes at the entries/exits. *Dis2Rdbuff* was derived by calculating the nearest distance from each small area to a 500m buffer around the primary roads and entries/exits to motorways. *Ln_CBD*, *Dist2Infor*, *Dist2Train*, and *Dis2Rdbuff* make up the rest of the location variables.

The degree of homogeneity or heterogeneity of the different ethnicities (consisting of Black African, Coloured, Indian or Asian, White, and Other), was calculated using the Herfindahl-Hirschman index (HHI) for each small area. This was normalised to the range between 0 and 100, so that values closer to 100 indicate more ethnic homogeneity within a small area, and values closer to 0 indicate more ethnic heterogeneity within a small area. This is represented by the *HHI* neighbourhood variable. It was decided that access to roads would be determined by using the primary/main roads (line shapefile) and the entry/exit nodes of motorways/highways as a combined data set. Finally, the average household income in Rands was calculated for each small area, from the census data collected, and converted into log form. It is represented by the variable *Ln_AvgHHIn*, which is also a neighbourhood variable.

For the final data sets containing the discussed variables, small areas with a Rand per m^2 value of 0 were removed (exclusively for each dependent variable), since this is the value we are trying to make estimations on. Features that had more than 50% of their area within protected areas were also removed. Since, technically residential development does not occur within protected areas, but some small areas overlapped with the protected areas, this is a reasonable way to account for this. Finally, outliers were identified in the dependent variables and within the income variable, which were also removed. In the end 4418 SAL features were used for the analysis on the Ln_Rm2 dependent variable and 4416 features were used for the Ln_Rm2dext variables.

Appendix A includes maps that illustrate the spatial patterns that each of these variables exhibit, which were visually assessed to determine the variables' viability for the study. After visual inspection of the maps, it was determined that they show a realistic representation of the spatial patterns that the variables would produce.

3.1.4. Hedonic Analysis

Initial Exploratory Analysis of Data

The above variables were finalised by first assessing the linear relationship between each exploratory variable and the dependent variable and assessing the R^2 values of these relationships. This was done for linear, semilog, quadratic, reciprocal, log, and log–log functional forms. The log–log functional form yielded best results for both the *Ln_Rm2* and *Ln_Rm2dext* dependent variables. Scatterplots and a Pearson's correlation in SPSS were used to detect potential multicollinearity between exploratory variables. *Mean_bed* and *Mean_bath* were found to be highly correlated, denoted by an r of 0.773. There was also a strong correlation between *Mean_bed* and *Dist2Infor*, and *Mean_bath* and *Dist2Infor*. These variables were kept in mind in case issues related to multicollinearity arose.

Ordinary Least Squares Regression

For each of the dependent variables an OLS model was run in ArcMap, using all independent variables. To assess for spatial autocorrelation, Moran's *I* was run on the residuals of the models. The results from these steps will be discussed in Chapter 4.

Geographic Weighted Regression

Based on the OLS models, it was determined that using all the independent variables explained both dependent variables well. However, *Ln_Rm2dext* was best estimated by the independent variables and therefore it was decided to assess only this dependent variable for the GWR analysis. Although, there was no evidence of multicollinearity in the global OLS model, trying to run the GWR will all the variables in ArcMap suggested that there may be local multicollinearity exhibited by the variables. Local multicollinearity is, however, difficult to identify. Removing the highly correlated variables and limiting the number of variables to no more than seven/eight allowed the model to run, but the results of this was suspect. Therefore, it was decided to use GWR in R, using the spgwr package. This was successful in running GWR using all variables, but it is important to know that this was computationally intensive. A Gaussian adaptive kernel, using CV, was utilised to determine the suitable number of neighbours for the bandwidth. Finally, Moran's *I* was used to test for spatial autocorrelation within the residuals.

CHAPTER 4: RESULTS & DISCUSSION

In this chapter, the results of the study are presented, evaluated and interpreted. The OLS and GWR models are discussed first in terms model performance and model specification. The effect of the exploratory variables on the dependent variable is then briefly discussed. This is followed be a closer inspection on the effects of the open space variables on the dependent variable, for both the global OLS and local GWR models.

4.1. COMPARISON OF MODELS

Table 4.1 summarises the main results for the OLS model using all the variables to estimate the *Ln_Rm2dext* dependent variable. To assess the models performance, we look at the R^2 and Adjusted R^2 values, which are 0.73731 and 0.73641 respectively. Based on the Adjusted R^2 value, the model explains approximately 74% of the variation in the dependent variable. The residual some of squares (RSS) value, which describes how well the model fits the data, is 326.

Table 4.1 OLS results for *Ln_Rm2dext* model.

OLS				
Variable	**Coefficient**	**StdError**	**Robust_Pr**	**VIF**
Intercept	7.246622	0.132346	0.000000*	--------
MEAN_BED	0.015433	0.008867	0.403824	3.139008
MEAN_BATH	0.064385	0.011353	0.016633*	5.144448
LN_CBD	-0.204277	0.009053	0.000000*	1.557482
DIST2INFOR	0.037144	0.003021	0.000000*	2.241223
DIST2TRAIN	0.012001	0.002745	0.000030*	1.324107
BUS_KM2	-0.000331	0.000245	0.192611	1.136668
SCHLWA_KM2	-0.009009	0.002010	0.000175*	1.250569
SHOPWA_KM2	0.018019	0.004372	0.000028*	1.061142
HHI	-0.000305	0.000181	0.183541	1.530860
DIS2RDBUFF	0.00001	0.000008	0.352865	1.175025
LN_POPDENS	-0.086439	0.005697	0.000000*	2.432411
LN_AVGHHIN	0.228138	0.009292	0.000142*	4.002500
RECWA_PERC	-0.000486	0.000716	0.45393	1.026665
PARKWA_PE	-0.006041	0.001455	0.000017*	1.139878
DIST2PA	-0.011579	0.002284	0.000003*	1.240944

RSS	326.00
R2	0.73731
Adjusted R2	0.73641
AICc	1057.75

Moran's *I*	
Moran's Index	0.262752
Expected Index	-0.000227
z-score	79.93
p-value	0.000000

The Corrected Akaike Information Criterion (AICc) for this model is 1057.75. It was expected that the coefficient signs of *Bus_km2*, *Schlwa_km2*, *Recwa_Perc* and *Parkwa_pe* would be positive. According to the Robust Probability values *Mean_bed*, *Bus_km2*, *HHI*, *Dis2RdBuff*, and *Recwa_Perc* are statistically insignificant. The rest of the variables are statistically significant (with p-values < 0.01). The VIF (Variance Inflation Factor) values are assessed to identify if any of the variables exhibit multicollinearity. Since none of the VIF values are above 7.5, there is no multicollinearity amongst variables.

The Koenker (BP) Statistic and Joint Wald Statistic were both statistically significant for this, indicating that the model itself is statistically significant. The Koenker (BP) Statistic also indicates that the model has statistically significant nonstationarity, making it a good candidate for GWR analysis. Concerning model bias, the Jarque-Bera Statistic was found to be statistically significant, which indicates model predictions are biased, based on the residuals not being normally distributed.

The table also shows the results from the Moran's *I* analysis of spatial correlation. Based on the fact that the p-value is statistically significant, the z-score is positive and the Moran's *I* value is positive, there is positive spatial autocorrelation between the residuals of this model (ESRI, 2016c; Cho, Bowker & Park, 2006). This means that high residual values tend to be neighbours of high values, intermediate values tend to be neighbours of intermediate values, and low values tend to neighbour other low values. Figure 4.1 maps the standardised residuals, and show this clustering pattern clearly. A biased model with a statistically significant spatial autocorrelation of residuals, may indicated model misspecification; meaning a key variable is missing from the model.

Since only two structural variables were used in this analysis, it would be logical to first identify potential key structural variables that could be missing. For example, age of house is a structural characteristic used in all of the studies reviewed that performed hedonic modelling for property value. However, due to lack of data for this variable it was not included in the study. Essentially, the data available mostly determines the variables used in the analysis. Also, there could be other unknown structural, environmental, and neighbourhood and location variables, not discussed in literature that could be key variables that impact property value specifically in the Cape Town Metropolitan area. Without being able to identify these variables, it is impossible then to include them in the hedonic analysis, and therefore misspecification of the model is inevitable.

Nonetheless, according to ESRI (2016b), results from a misspecified model cannot be trusted. However, the misspecification may be a result of trying to model nosnstationary variables using a global model (ESRI, 2016d).

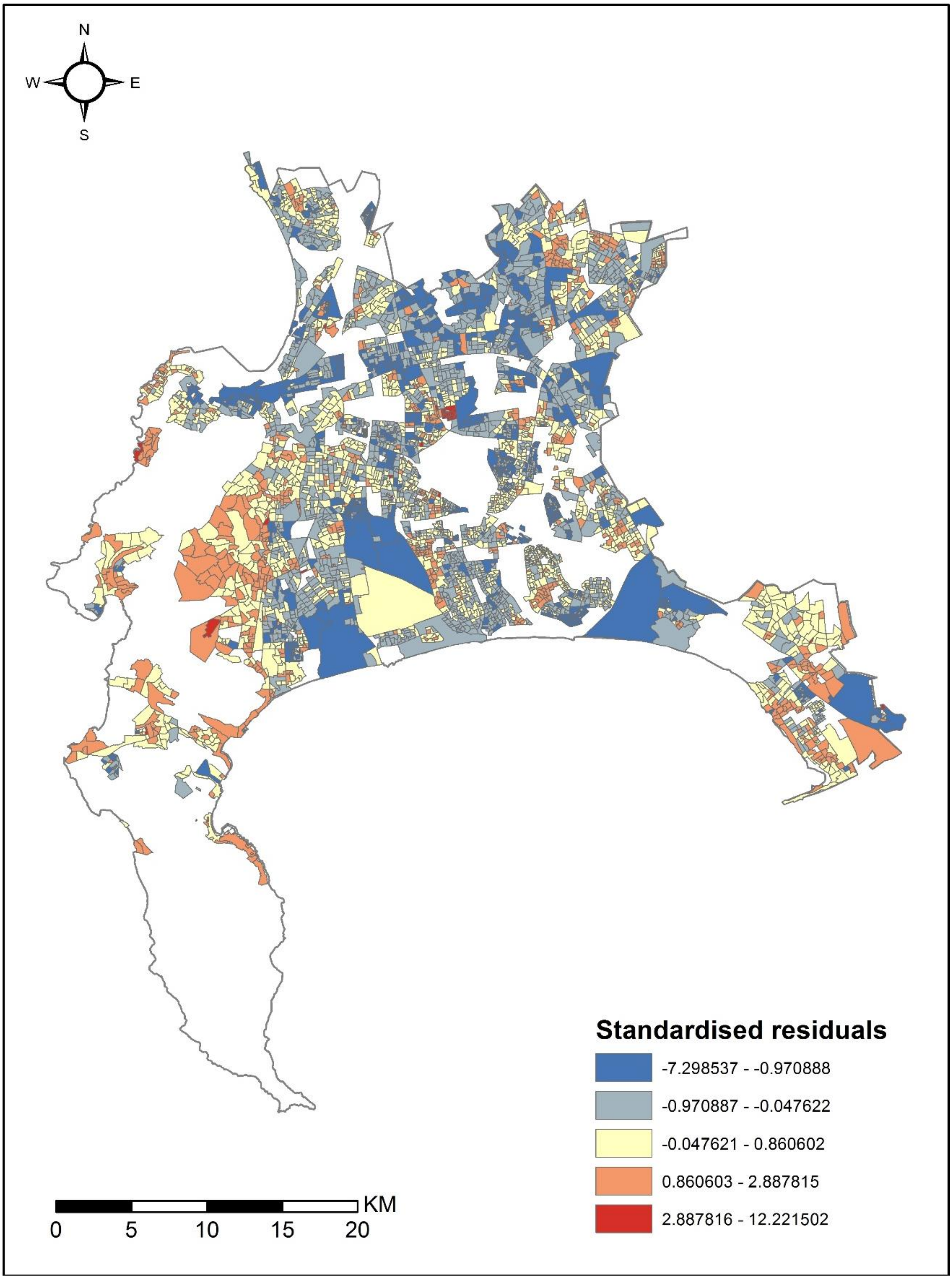


Figure 4.1 Map of standardise residuals from OLS model.

Pavlov (2000) suggests the incorporation of location into the hedonic analysis, spatial varying coefficients can be estimated, can address spatial autocorrelation. Therefore, GWR may be used to improve predictions and to better understand local variation exhibited by the variables (ESRI, 2016d).

For comparison, the OLS model for the *Ln_Rm2* dependent variable, which used 4418 features, obtained the following results: An R^2 value of 0.62660, an Adjusted R^2 value of 0.62533, an RSS value of 770.87, and an AICc value of 4858.39. Concerning the independent variables, it was expected that *Mean_bath* and *Parkwa_pe* would have a positive coefficient sign and *Ln_Popdens* would have a negative sign, and the only variable that is statistically insignificant is *Recwa_perc*. None of the variables indicate multicollinearity in this model as well. This model is also statistically significant and exhibits statistically significant nonstationarity. Same as the *Ln_Rm2dext* model, it is biased and has positive spatial autocorrelation of residuals, indicating potential model misspecification.

As mentioned before, the Ln_Rm2dext OLS model was chosen for the GWR analysis. Table 4.2 presents the main results of the GWR model. The adaptive kernel calculates a proportion between 0 and 1 of the features to include in weighting scheme, to calculate local bandwidth. This value is 0.00310562, which means approximately 13 features (0.00310562 multiplied by the total 4416 features) were used for the adaptive kernel. The R^2 for the model is 0.960863, the RSS 48.56979, and the AICc -5818.95. The spgwr package does not provide an Adjusted R^2 so only the R^2 can be used to judge model performance; although the Adjusted R^2 would only be a little less than the R^2. The spgwr package does not also provide means to identify local multicollinearity within a GWR model. Even so, from the values provided, the GWR improves on the OLS, suggesting that the local model fits the data better than the global OLS model.

It is evident that there is negative spatial autocorrelation of the residuals of this model. This is shown by the statistically significant p-value, negative z-score, and negative Moran's *I* value. This means that residual values are dispersed and not clustered, as in positive spatial autocorrelation (ESRI, 2016c; Cho, Bowker & Park, 2006). High residual values tend to be neighbours of low values, intermediate values tend to be neighbours of intermediate values, and low values tend to neighbour other high values, in this case. Figure 4.2 maps the standardised residuals of this model which exhibit the checkered pattern that is typical of dispersed features. The magnitude of the Moran's *I* value of -0.011473 in this model, is less than that of the global model's Moran's *I* value of 0.262752. This indicates that the local GWR model reduced the magnitude of the Moran's *I* value from the OLS model substantially. However, the statistical significance of the Moran's *I* value for the local model means that statistical results must be treated with caution (Cho et al., 2009). Essentially, this model indicates some other additional spatial processes in the data (variables) and potential misspecification of the model.

Table 4.2 GWR results for *Ln_Rm2dext* model.

GWR						
Variable	**Global Coeff**	**Min.**	**1st Qu.**	**Median**	**3rd Qu.**	**Max.**
X.Intercept.	7.24660	-263.90000	4.08460	8.26960	13.66100	135.52000
Mean_bed	0.01540	-0.75873	-0.20314	-0.05206	0.07596	0.64850
Mean_bath	0.06440	-2.91300	-0.11783	0.04266	0.19917	1.52090
Ln_CBD	-0.20430	-34.34200	-1.75340	-0.08936	1.18800	83.21800
Dist2Infor	0.03710	-1.28360	-0.04736	0.03415	0.11949	1.26730
Dist2Train	0.01200	-1.74000	-0.06127	0.03141	0.11940	1.44630
Bus_km2	-0.00030	-0.04875	-0.00196	-0.00048	0.00050	0.10558
Schlwa_km2	-0.00900	-0.15067	-0.01842	-0.00473	0.00497	0.37432
Shopwa_km2	0.01800	-438.86000	-0.03318	-0.00129	0.03651	1745.50000
HHI	-0.00030	-0.01137	-0.00223	-0.00055	0.00104	0.01035
Dis2RdBuff	0.00000	-0.00187	-0.00010	0.00001	0.00012	0.00118
Ln_Popdens	-0.08640	-0.50965	-0.06759	-0.02223	0.00890	0.25900
Ln_AvgHHIn	0.22810	-0.64484	0.00776	0.07800	0.18559	0.57858
Recwa_perc	-0.00050	-2385.20000	-0.00567	-0.00054	0.00370	599.85000
Parkwa_pe	-0.00600	-0.10565	-0.00762	0.00127	0.01037	0.30020
Dist2PA	-0.01160	-2.62550	-0.12972	-0.02318	0.08852	2.40770

Adaptive quantile	0.00310562 (about 13 of 4416 data points)
RSS	48.56979
Quasi-global R2	0.960863
AICc	-5818.95

Moran's *I*	
Moran's Index	-0.011473
Expected Index	-0.000227
z-score	-5.26
p-value	0.000000

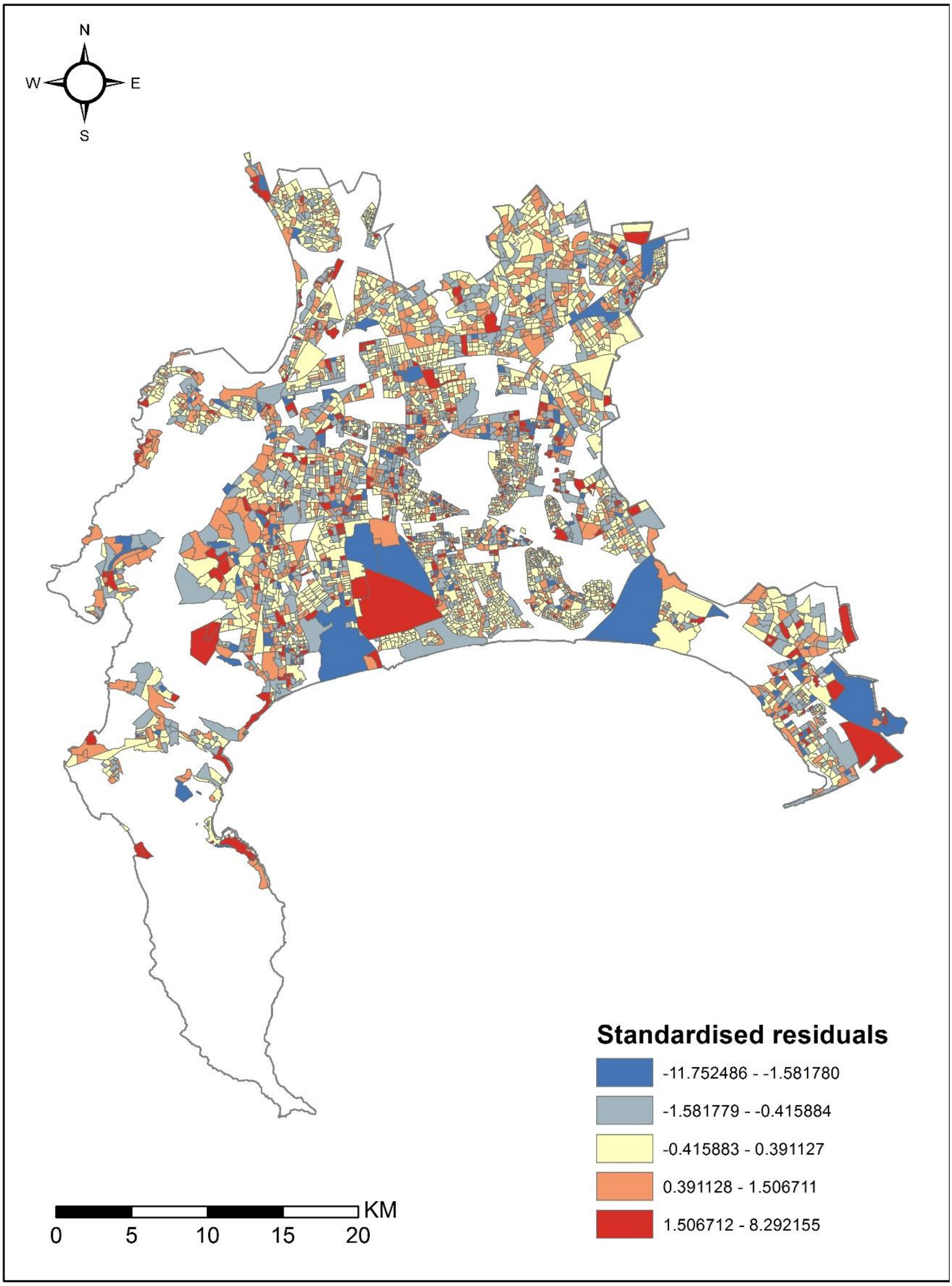


Figure 4.2 Map of standardise residuals from OLS model.

4.2. ESTIMATED COEFFICIENTS OF EXPLORATORY VARIABLES

The relationship between each of the exploratory variables and the dependent variable (or the effect of each exploratory variable on the dependent variable) are now evaluated, while keeping potential misspecification of the above models in mind. Table 4.3 summarises the relevant parameter estimates of each of the variables, from the two models.

Table 4.3 Parameter estimates from OLS and GWR models.

	OLS		GWR				
Variable	**Coefficient**	**StdError**	**Min.**	**1st Qu.**	**Median**	**3rd Qu.**	**Max.**
Intercept	7.246622	0.132346	-263.90000	4.08460	8.26960	13.66100	135.52000
MEAN_BED	0.015433*	0.008867	-0.75873	-0.20314	-0.05206	0.07596	0.64850
MEAN_BATH	0.064385	0.011353	-2.91300	-0.11783	0.04266	0.19917	1.52090
LN_CBD	-0.204277	0.009053	-34.34200	-1.75340	-0.08936	1.18800	83.21800
DIST2INFOR	0.037144	0.003021	-1.28360	-0.04736	0.03415	0.11949	1.26730
DIST2TRAIN	0.012001	0.002745	-1.74000	-0.06127	0.03141	0.11940	1.44630
BUS_KM2	-0.000331*	0.000245	-0.04875	-0.00196	-0.00048	0.00050	0.10558
SCHLWA_KM2	-0.009009	0.002010	-0.15067	-0.01842	-0.00473	0.00497	0.37432
SHOPWA_KM2	0.018019	0.004372	-438.86000	-0.03318	-0.00129	0.03651	1745.50000
HHI	-0.000305*	0.000181	-0.01137	-0.00223	-0.00055	0.00104	0.01035
DIS2RDBUFF	0.00001*	0.000008	-0.00187	-0.00010	0.00001	0.00012	0.00118
LN_POPDENS	-0.086439	0.005697	-0.50965	-0.06759	-0.02223	0.00890	0.25900
LN_AVGHHIN	0.228138	0.009292	-0.64484	0.00776	0.07800	0.18559	0.57858
RECWA_PERC	-0.000486*	0.000716	-2385.20000	-0.00567	-0.00054	0.00370	599.85000
PARKWA_PE	-0.006041	0.001455	-0.10565	-0.00762	0.00127	0.01037	0.30020
DIST2PA	-0.011579	0.002284	-2.62550	-0.12972	-0.02318	0.08852	2.40770

Evaluated at the mean Rand per m^2 of 7 091.80 (see Table 3.2), the results indicate that the property value (expressed as Rand per m^2 of a dwelling extent), increases by 1.54% or R109.00 per m^2, per additional bedroom if all other variables are fixed. This is, however, not statistically significant. Although in the global model the coefficient for *Mean_bed* is positive, the GWR model indicates that more than half of the features result in a decrease in property value, which is not expected. This means that the magnitude of the positive coefficients must be greater than the magnitude of the negative coefficients. For the second structural variable, an additional bathroom increases property value by 6.44% or R456.00 per m^2, if everything else is fixed. This is statistically significant, and more than half of the coefficients estimated by the GWR model for *Mean_bath* are positive.

For the environmental variables, although statistically insignificant, an additional bus stop decreases property value by 0.03% or R2.00 per m^2 if everything else is fixed. An additional school decreases property value by 0.90% or R63.00 per m^2 if all other variables are fixed. If everything else is fixed, an additional shopping centre increases property value by 1.80% or R127.00 per m^2. Property value decreases by 0.09% or R6.00 per m^2 with 1% increase in population density, if all other variables are fixed. These three variables are statistically significant. A 1% increase in recreational area decreases property value by 0.05% or R3.00 per m^2 if all other variables are fixed; but this is not statistically significant. If all other variables are fixed, property value also decreases by 0.60% or R42.00 per m^2 per 1% increase in park area, and this is statistically significant.

For the location and neighbourhood variables, property value decreases by 1.16% or R82.00 per m^2 when distance to nearest protected area increases by a kilometre, if everything else is fixed. Property value decreases by 0.20% or R14.00 per m^2 with a 1% increase in distance to the CBD, if all other variables are fixed. A 1km increase in distance to nearest informal settlements increases property value by 3.71% or R263.00, if all other variables are fixed, and a 1km increase in distance to nearest train station increases property value by 1.20% or R85.00, if all other variables are fixed. If everything else is fixed, a 1% increase in average household income increases property value by 0.23% or R16.00. All of these variables are statistically significant. 1% increase in HHI (representing the degree in ethnic homogeneity/heterogeneity) results in a decrease in property price by 0.03% or R2.00 per m^2, if all other variables are fixed. These two variables are however, statistically insignificant.

4.3. OPEN SPACE & PROPERTY VALUE

The results of the global OLS model indicate that more provision of recreational areas and parks has a negative impact on property value, within the Cape Town metropolitan area. The magnitudes of these negative relationships, however, are not substantial, with a 1% increase in recreational area resulting in a decrease in property value by 0.05% (if all other variables are fixed), and a 1% increase in park area decreasing property value by 0.60% (if all other variables are fixed). These findings thus differ from the findings of other studies that have performed hedonic analysis using global models with the open spaces types primarily consisting of parks and/or recreational areas, and which found a positive relationship between open space and property value (Anderson & West, 2006; Bolitzer & Netusil, 2000).

This could be due to the way the open space variables were constructed in this study, where proximity or access to open space is based on the percentage of area of open space within a small area and its adjacent small areas. This was to account for the aggregation to SAL level. Typically, distance to open space is used as a variable in hedonic modelling. Bolitzer & Netusil (2000) use this type of variable in their study and so do Anderson & West (2006), who also provide size/area of open space in their study. The addition of a distance to open space variable may yield different or positive relationships between these open space types and property value. However, this would not make sense for the small area entities since ultimately all parks and recreational areas fall within the small areas; meaning this would only work for disaggregated property value features.

The fact that the impact of recreational areas on property value is also statistically insignificant, means more information on the specific types of recreational areas should be provided, as suggested by Bolitzer & Netusil (2000). For example, the recreational areas variable is made up of a number of open space features provided for recreational use. Sport fields and golf courses both fall under the recreational areas variable, but they might have different impacts on property value. Intuitively, it can be assumed that access to golf courses may have a greater impact on property value than access to sports fields.

On the other hand, the negative relationships between recreational areas and parks, and property value respectively, could be a legitimate representation of reality; even if it is not expected. If so it could be due to potential negative aspects associated with open spaces, such as crime and drug use (Francis, 1987), or the fact that large and flat open spaces, such as sportsfields are sometimes seen as less desirable than other open space types (Crompton, 2000). It could also be that people do not value parks and recreational areas as much as literature does, for this particular study area.

For the distance to protected areas variable, the relationship between this open space type and property value is positive. This is indicated by property value increases by 1.16% when distance to nearest protected area decreases by a kilometre, if everything else is fixed. Meaning, as one lives closer to a protected area, property value increases because of it. This is also not a substantial impact, but is larger than the magnitudes of the impact recreational areas and the impact of parks. The protected areas variable consists of open spaces types that are natural and under conservation, and includes the Table Mountain National Park located (located in west of the study area). This coincides with literature that use these types of open spaces in their studies, using global models (Geoghegan, Lynch & Bucholtz, 2003; Pearson, Tisdell & Lisle, 2002).

The construction of this variable may have a part in the resultant relationship, since distance to protected areas could be used in the study because the protected areas do not (more or less) fall within the small areas. The aggregated open space types within this variable could also have similar impacts on property value. Considering the resultant relationship solely, residents in the Cape Town Metropolitan areas could in reality value the protected areas in a positive light, perhaps because they offer more natural and scenic settings.

These findings suggest that merely having access to open space may not provide a proper indication of the impact of open space on property value, but what an open space offers, may do so. Therefore, a disaggregation of the open space variables into more open space type variables could prove to be more effective. An indication of open space quality within the analysis could also be very helpful. The results from the global model generalise the relationship between the open space types and property value into single values, without considering that the property values of different areas within the study area, may be affected differently by open space depending on where they are located. The use of a local model essentially provides locational context and allows variation of impact on property values to be identified and assessed.

Table 4.3 indicates that in the local GWR model, more than half of the estimated coefficients for *Recwa_perc* are negative, and the negative global coefficient indicates that the number and magnitude of the negative local coefficients is greater than that of the positive coefficients. For *Parkwa_pe* however, more than half are positive even though its global coefficient is negative, meaning although the negative local coefficients are less, their combined magnitude is greater than that of the positive local coefficients. For *Dist2PA* more than half of the local coefficients are negative, indicating a greater number and magnitude of negative local coefficients than the positive coefficients for this variable.

It is however, difficult to interpret these findings without knowing how exactly these negative and positive coefficients are spatially distributed. Therefore, to get a good idea of local impacts of open space on property value, coefficient maps, each mapping the local coefficients of each of the open space variables, were created. For the *Recwa_perc* variable, 17 extreme coefficients were identified and subsequently removed. As can be seen in Figure 4.3, most of local coefficients of *Recwa_perc* are very close to the value of 0, meaning that there is only substantial impact on property value in a few areas. Strong positive impacts on property value by recreational areas are more or less well distributed in the entire study area, and strong negative impacts are scarce with one cluster in the North of the study area, another in the South East, and another in the South West (adjacent to very strong impacts on property value). Very strong positive impacts on property values occur in a small cluster of small areas in the South East of the study areas. There is also

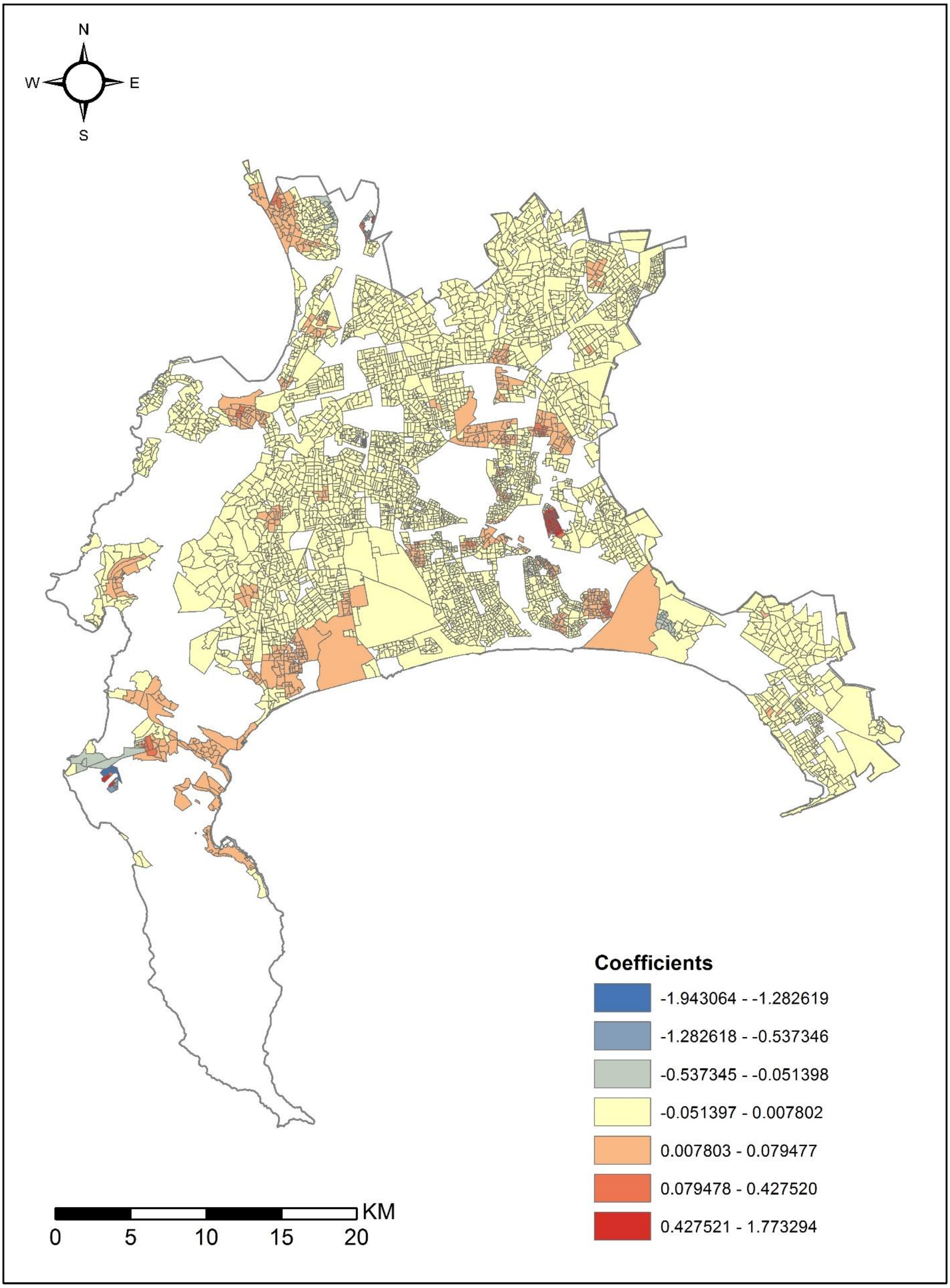


Figure 4.3 Local coefficients of *Recwa_perc*.

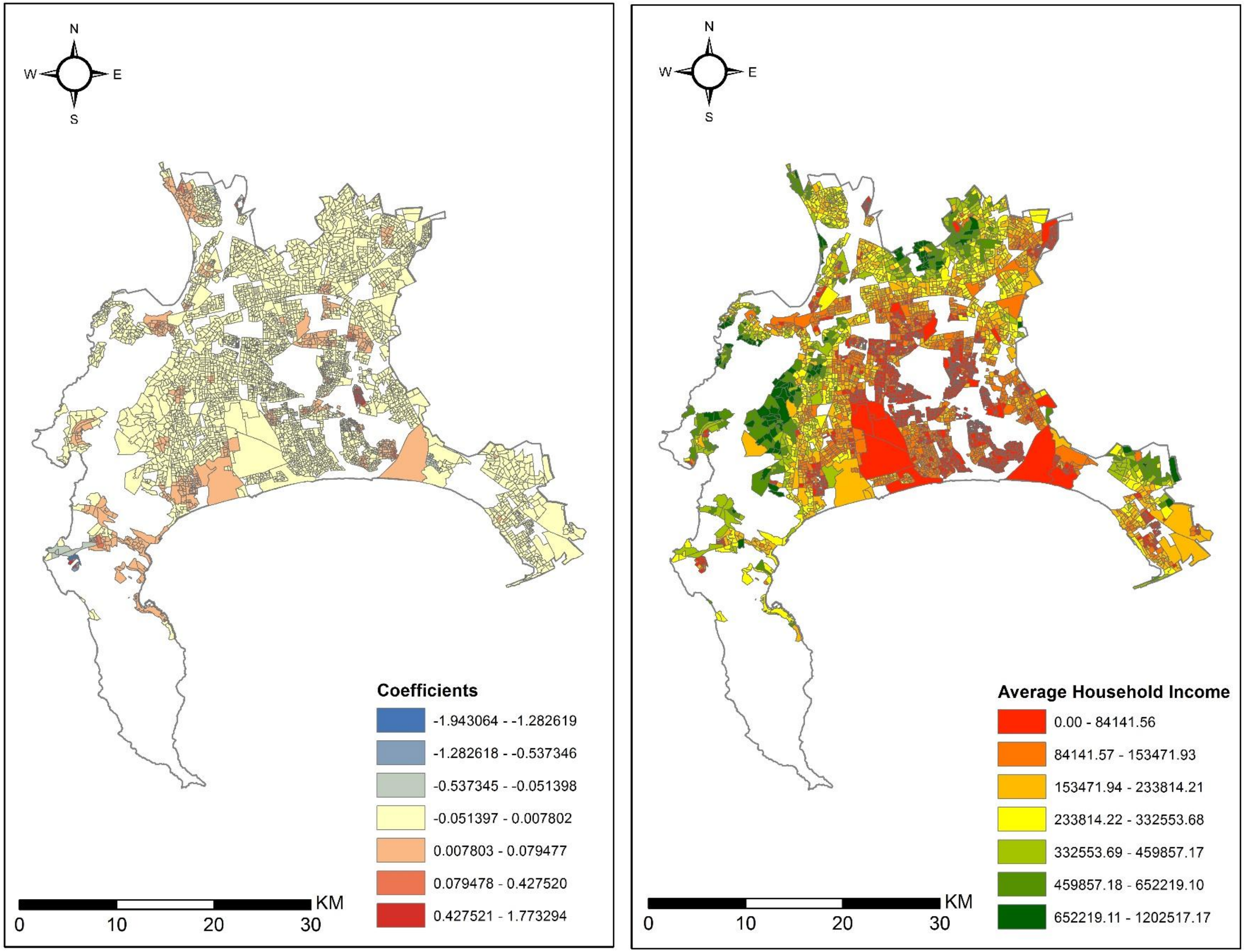


Figure 4.4 Comparison between *Recwa_perc* local coefficients and average household income.

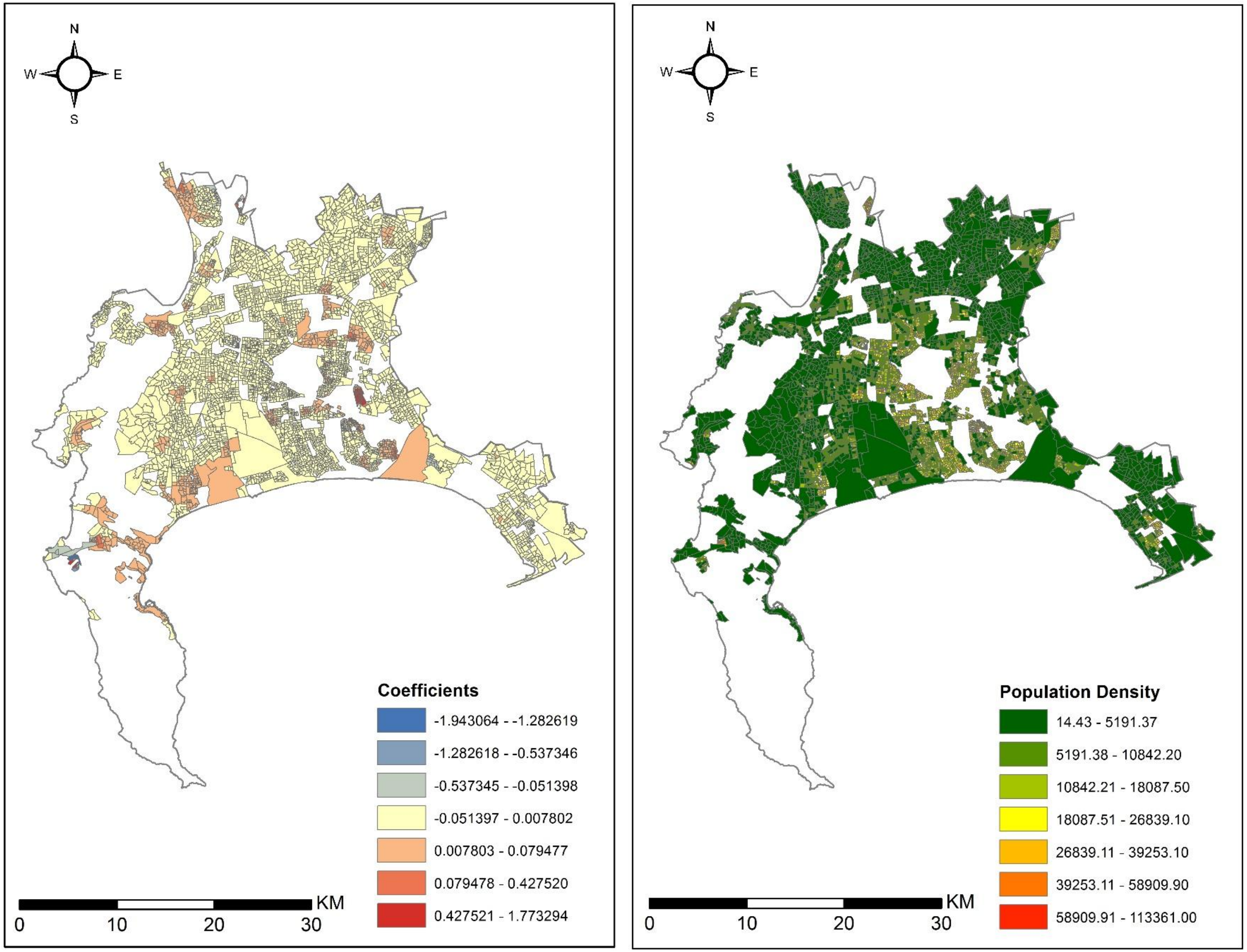


Figure 4.5 Comparison between *Recwa_perc* local coefficients and population density.

very strong positive impact clustered with very strong negative impacts on property values, located in the South West of the study area.

Figure 4.4 compares the map of the impact of recreational areas on property value with a map illustrating the average household income in the metropolitan area. As indicated, areas that show strong positive impact on property value by recreational areas are generally located in the same areas as small areas indicating lower ranges of household income. This means that proximity to recreational areas in poorer communities is most likely to improve property value, whereas in other communities there is little affect. In relation to population density, areas indicating strong positive impact on property value coincide mostly with areas of low population density. This depicted in Figure 4.5.

The *Parkwa_pe* local coefficients exhibit more variation, with more strong and very strong impacts on property value by parks easily identifiable, in Figure 4.6. The most notable is a cluster of very strong positive impacts located West of the study area. Figure 4.7 compares impacts on property value with the average household income map. Here the very strong and positive impact on property value in the West coincides with a cluster of small areas with very high income. Another cluster of high income values, also in the West and is close to but separated from the other smaller cluster by a protected area entity, matches with small areas indicating very little impact on property value by parks. This is interesting since these clusters are relatively close to each other, and the bigger cluster is in fact surrounded by parks to the East of it. The distribution of parks within the study area is not mapped because it would be difficult to identify the park features. Strong positive impacts on property value by parks coincide with medium and low income areas. The strong negative impacts on property values mostly match the areas with low and medium income values. Ultimately, Figure 4.7 also shows that mostly weak negative impacts on property values cover the metropolitan area, which coincides with all of the different types of income levels; with the few exceptions just discussed. This generally more of a negative impact on property value by parks is clearly illustrated in this coefficient map. Figure 4.8 indicates that both negative and positive impacts on property value that are strong and very strong, coincide with areas of lower densities.

For the last open space variable, *Dist2PA*, there is also distinctive variation in the local coefficient values. An increase in distance to protected areas should result in higher property value, or in other words, it should result in stronger negative impacts on property value. Figure 4.9, mostly shows weak negative impacts on property value. There are strong and very strong positive impacts located in the centre of the study area, and two clusters in the North. This makes sense since these are not very close to the protected areas. However, a cluster in the West (the

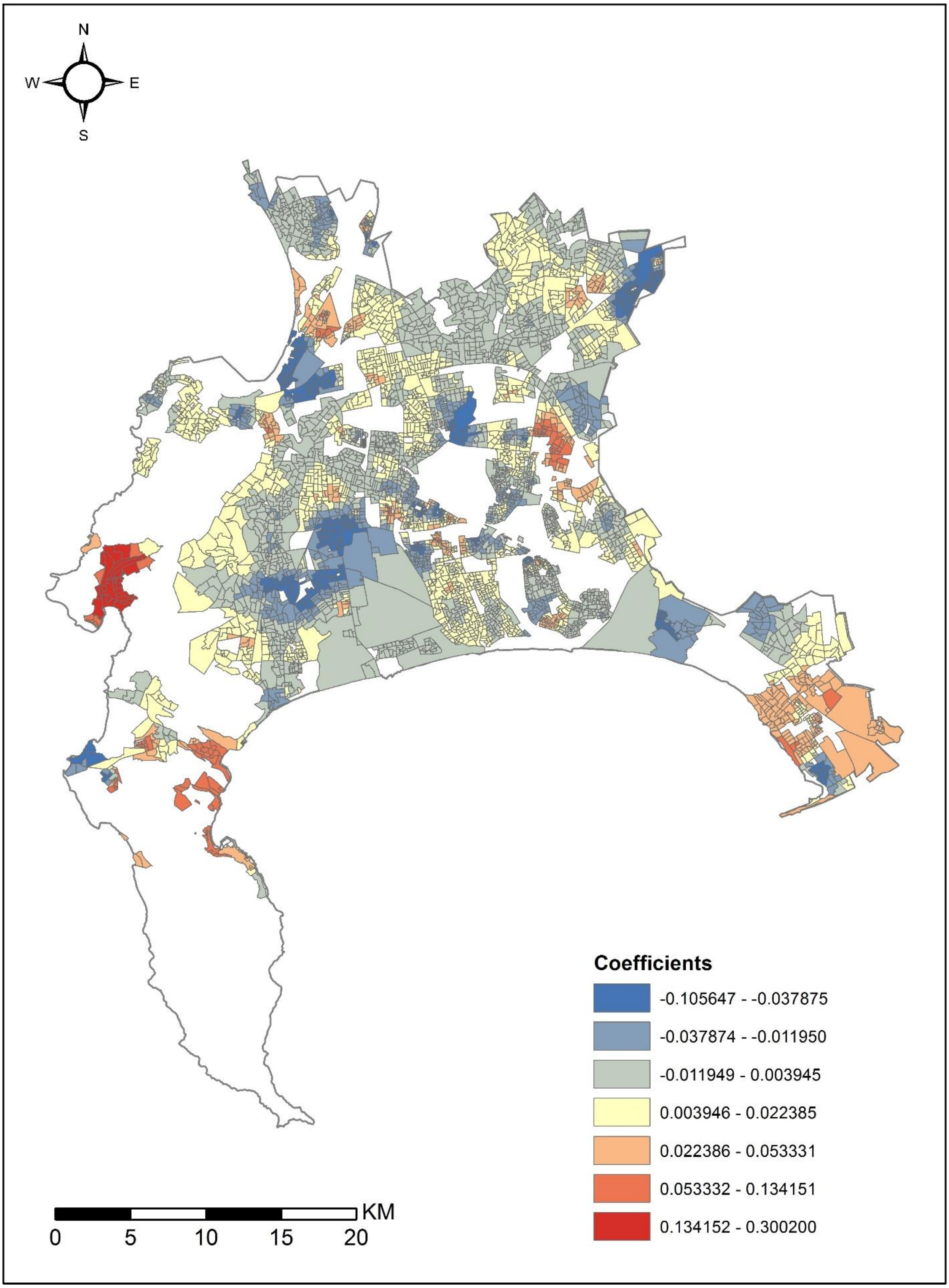


Figure 4.6 Local coefficients of *Parkwa_pe*.

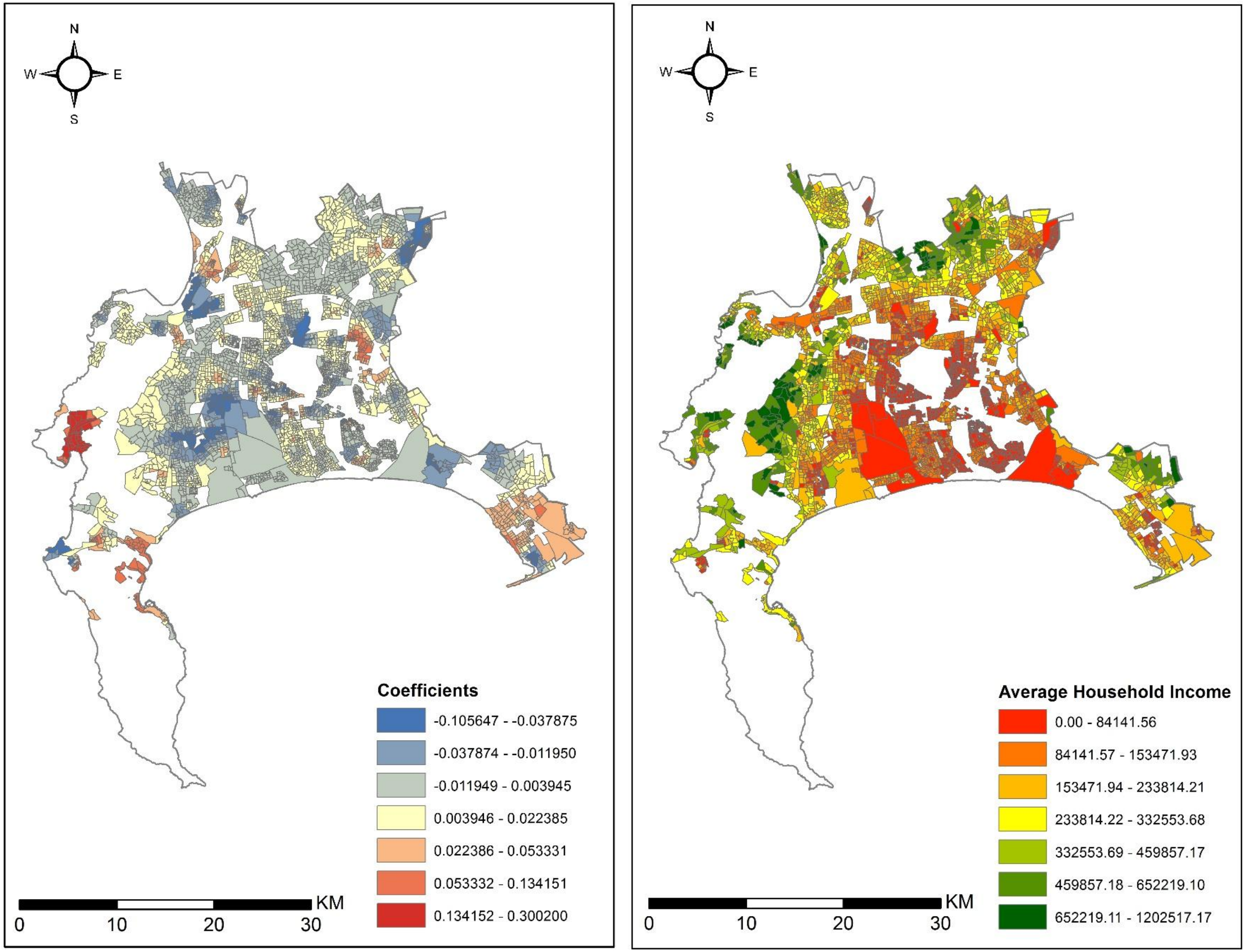


Figure 4.7 Comparison between *Parkwa_pe* local coefficients and average household income.

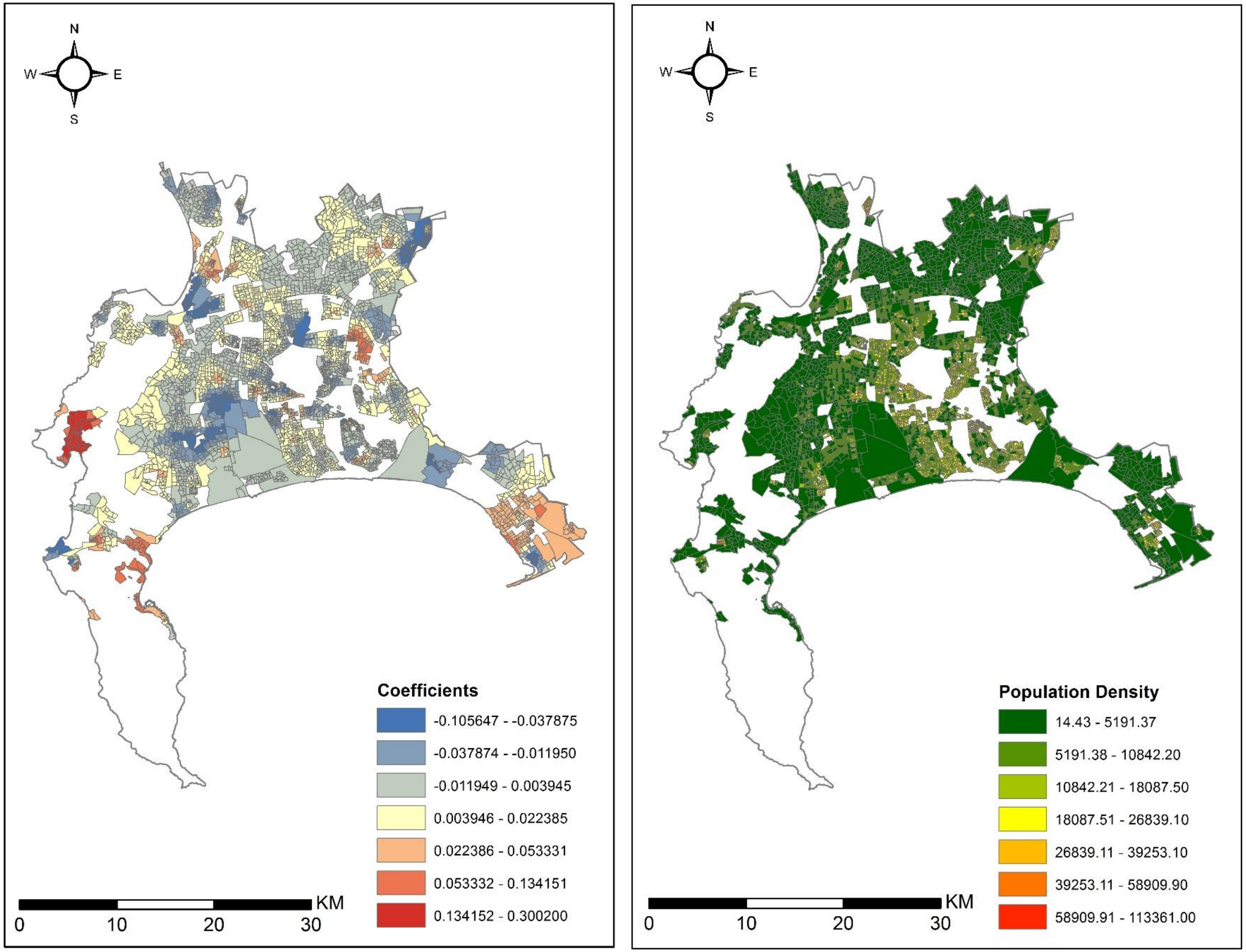


Figure 4.8 Comparison between *Parkwa_pe* local coefficients and population density.

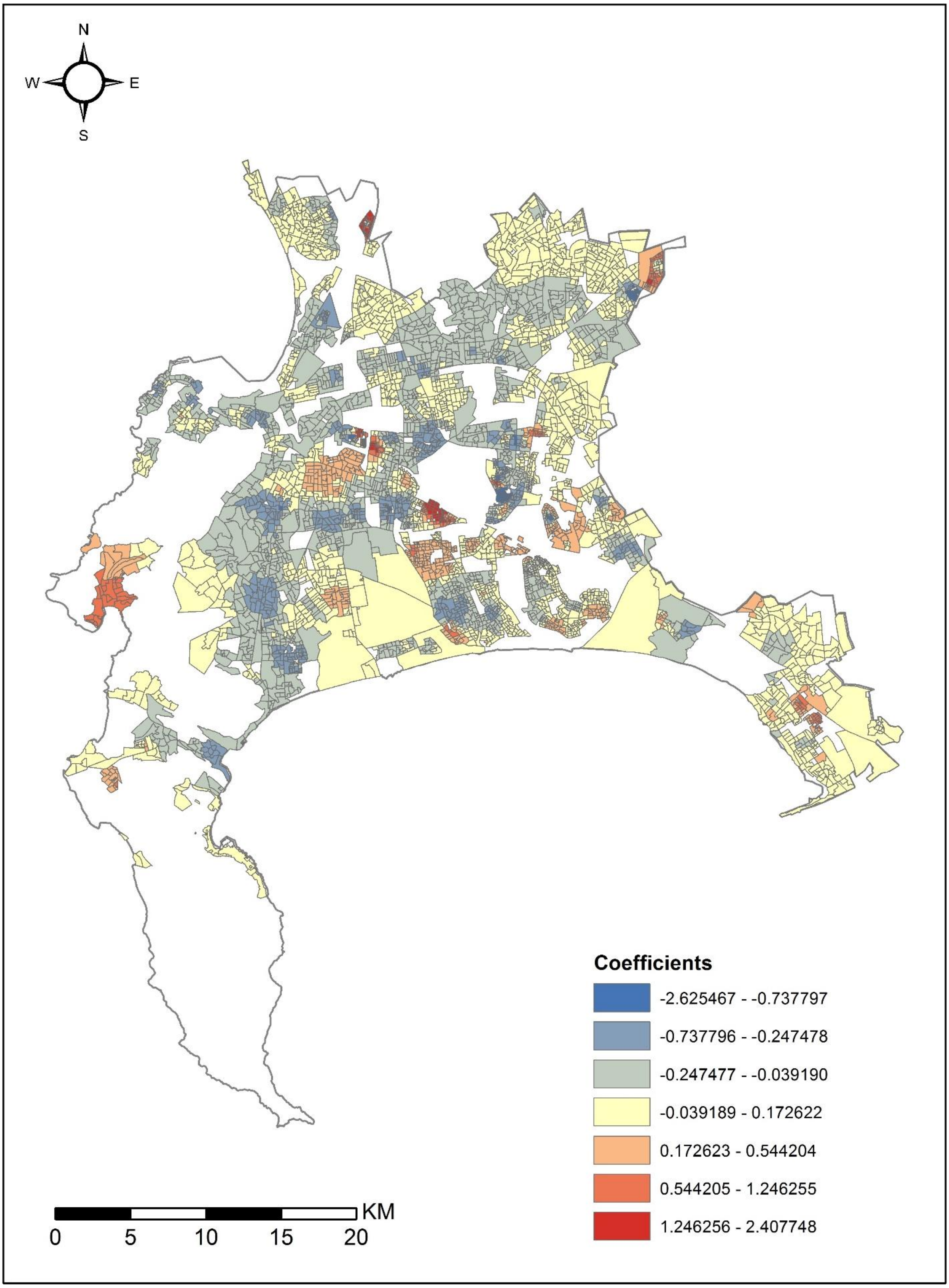


Figure 4.9 Local coefficients of *Dist2PA*.

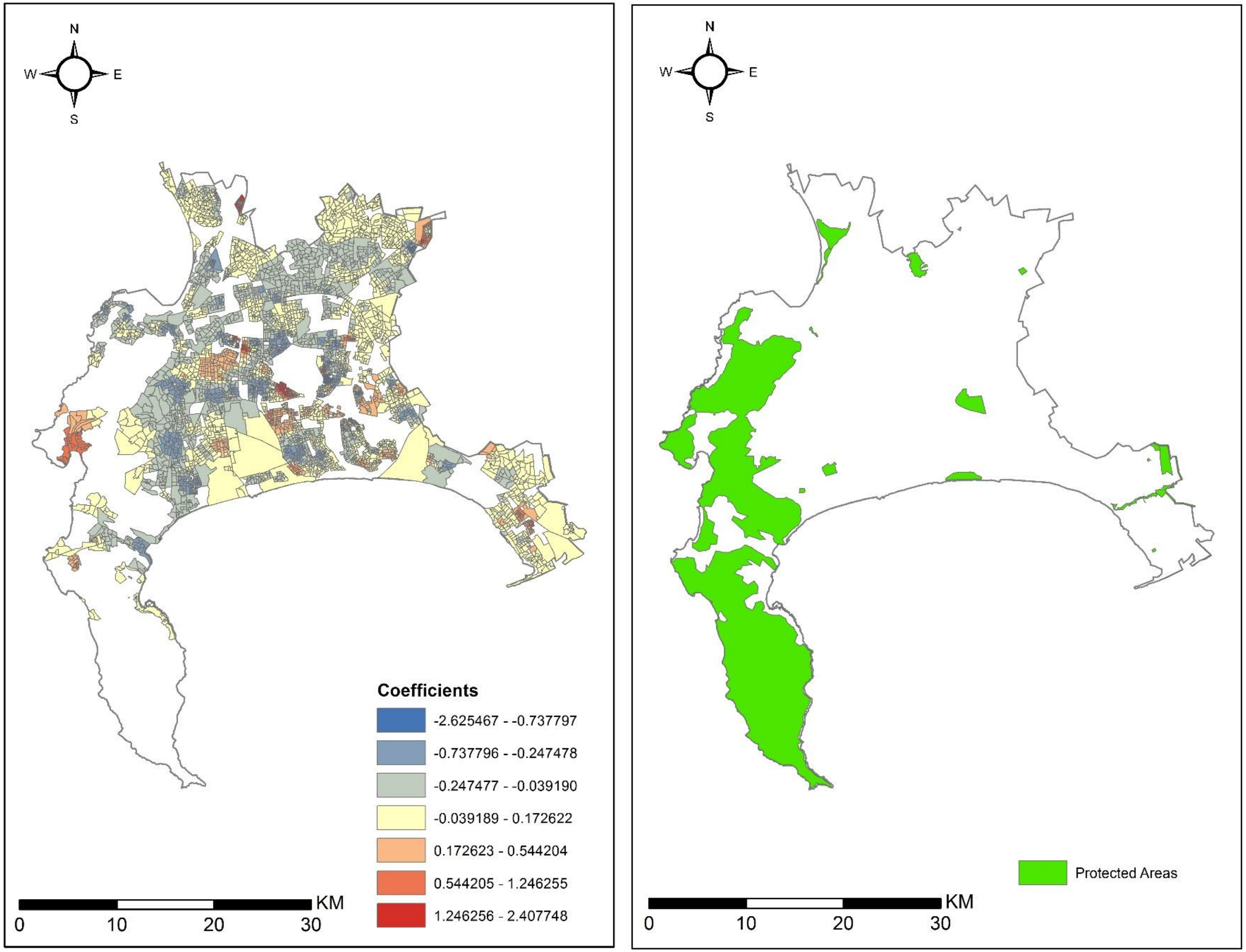


Figure 4.10 Comparison between *Parkwa_pe* local coefficients and protected area features.

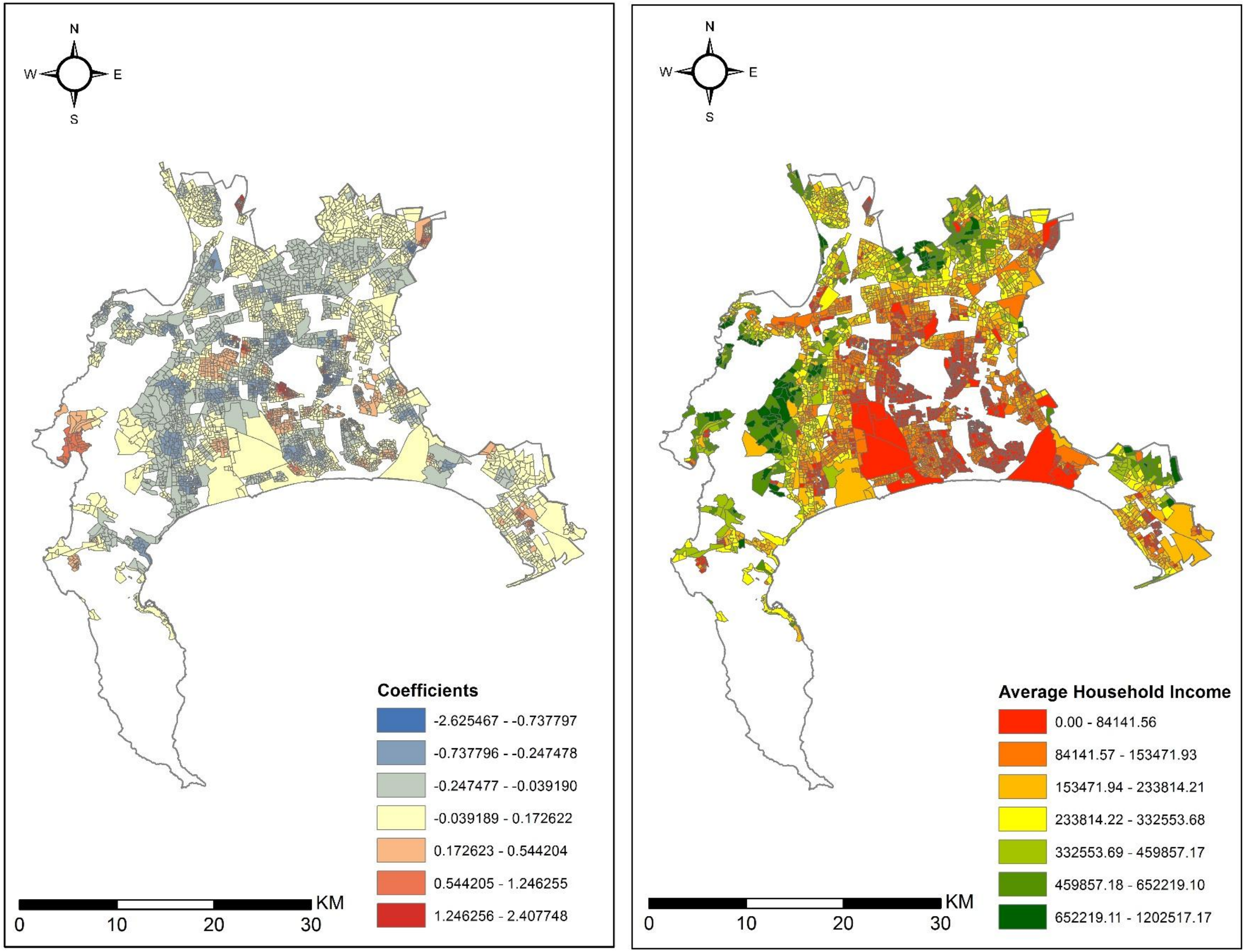


Figure 4.11 Comparison between *Dist2PA* local coefficients and average household income.

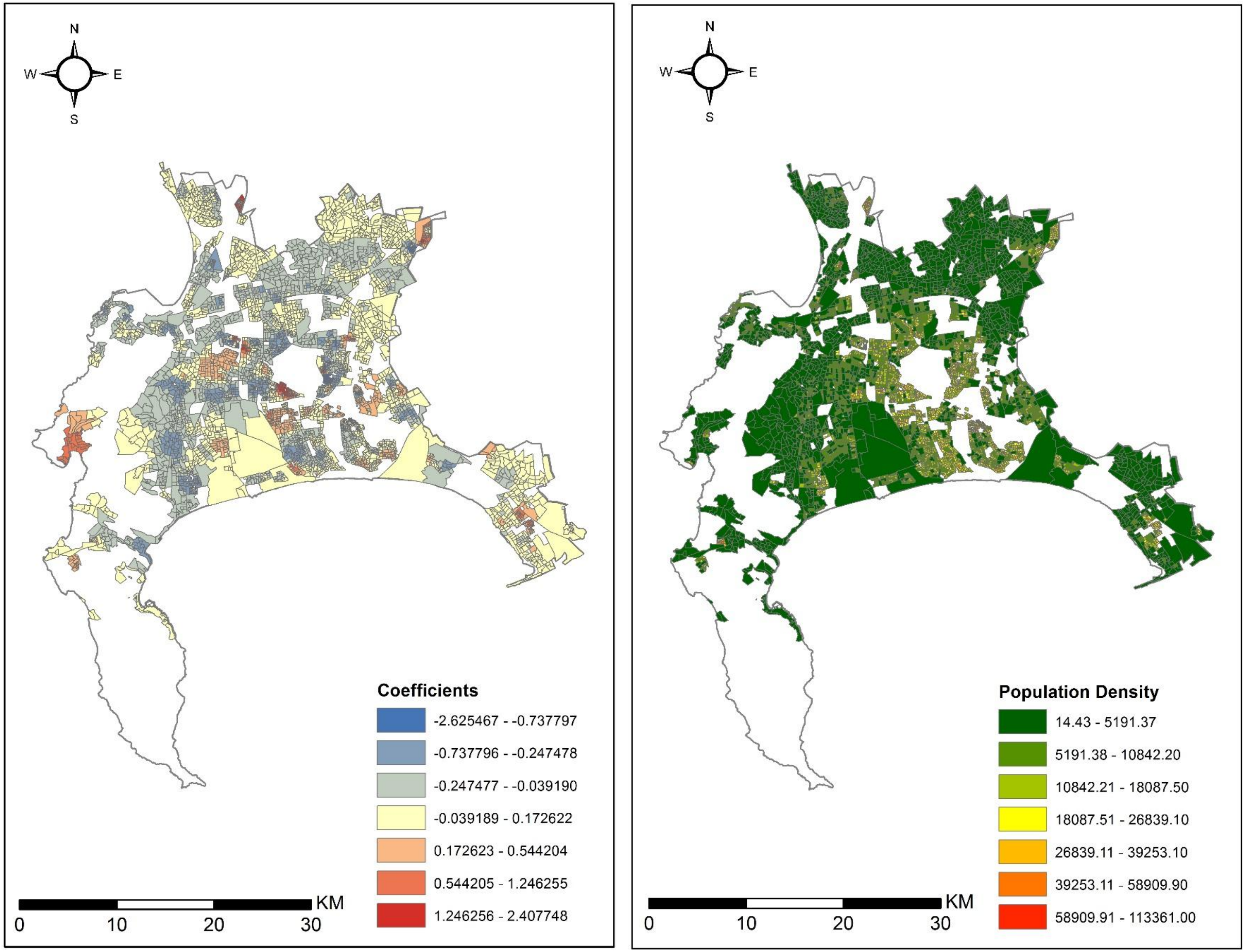


Figure 4.12 Comparison between *Dist2PA* local coefficients and population density.

same one discussed previously), also indicates positive impacts on property value, even though it is almost entirely surrounded by protected area features. This means, for this particular cluster, property that is closer to protected areas, will decrease in values. Figure 4.10 compares *Dist2PA*'s local coefficients to a map containing the protected areas entities, giving a clear indication of where the protected areas are located in relation to the small areas. All of the centre and Northern positive impacts on property value coincide with areas of lower income (see Figure 4.11). This implies that properties located furtherer away from protected areas are more likely to be poorer communities. The cluster of small areas in the West is the only one that coincides with areas of relatively high income. Figure 4.12 indicates that the clusters of positive impacts centre and Northern positive impacts on property value coincide with areas of mixed or higher densities. The small cluster of positive impact on property in the West, again shows the opposite, since it coincides with areas of low density. The negative impacts on property value more or less match areas of low density as well.

The findings on proximity to protected areas are consistent with what is presented in literature, whereas the findings on proximity to recreational areas and parks are inconsistent. This indicates that the type or function of open space plays a role in assessing the relationship between open space and property value. Identifying the use of open spaces at more detail and not at such broad categories could also give a better understanding of the results presented. For example, a well maintained recreational area or park will be most likely used and valued by its local neighbourhood or community, whereas an open spaces designated as a recreational area or park and is not looked after will not be used, and will be regarded as undesirable. In South Africa, safety is a major issue for residents, in terms of crime. For both affluent and poorer neighbourhoods open spaces could be seen as areas that attract vagrants and dangerous people aiming to rob and hurt residents. The Western Cape also experiences many hazardous fires, especially during its dry season, and living close to open spaces prone to fires could be regarded undesirable for residents. Therefore, these issues could be considered and may better explain the presented inconsistencies.

CHAPTER 5: CONCLUSION

The aim of this study was to determine and assess the relationship between open space and residential property value in the Cape Town Metropolitan area. The aim was achieved by fulfilling two objectives. The first objective was determining the relationship between residential property and each of the open space types used in this study, based on access to open space. This objective was achieved by performing a hedonic analysis on structural, environmental, neighbourhood and location characteristics of properties within the study area. Essentially objective two, which was to determine the relationship at both global (and more importantly) local level, was achieved at the same time as objective one, since a global OLS model and a local GWR model were used to perform the hedonic analysis to obtain global and local results, respectively.

5.1. MAIN FINDINGS

The OLS model determined that there is a negative but weak relationship between access to recreational areas and property value, with a 1% increase in recreational area resulting in a decrease in property value by 0.05% of R3.00 per m^2 (if all other variables are fixed). A negative and weak relationship also exists between access to parks and property value, with a 1% increase in park area decreasing property value by 0.60% or R42.00 per m^2 (if all other variables are fixed). Finally, there is a positive and relatively weak relationship between access to protected areas and property value, which is described by property value increasing by 1.16% or R82.00 per m^2 when distance to nearest protected area decreases by a kilometre (if all other variables are fixed).

Global results essentially assign a value for the entire study area, thereby generalising the relationship between each of the open space types and property value. This therefore does not consider that the property values of different areas within the study area, which may be affected differently depending on where they are located. The GWR model, therefore takes locality and spatial variation into account. The main results for the local model found that there is little variation between the impact of access to recreational areas on property value within the study area. However, there is evidence that in general small areas that are highly impacted by proximity to recreational areas, exhibit low average household income values and low population density values.

The impact of access to parks on property value shows more variation within the study area, with areas characterised by both strong negative and positive impacts on property value coinciding with medium and lower incomes, and lower population densities. Also, for the parks variable, there is a prominent weak negative impact on property value throughout the study area. For the impact of access to protected areas, in general, small areas showing positive impacts on property value, contain lower incomes and consist of mixed and higher population densities. This means that as you get further away from protected areas, the property value should decrease, the income values should start to drop and the population densities should start to increase. However, there are exceptions that are found and cannot be readily explained, without knowing what is actually happening in the specific locations in reality. Local modelling at least offers a way of finding these exceptions, which can be further investigated.

Based on these findings, the first part of the hypothesis of there being a positive relationship between access to open space and residential property value is rejected for all open space types. It is only accepted for the findings for the protected areas open space category. The second part of the hypothesis of the impact on residential property value varying according to the type of open space is accepted.

5.2. LIMITATIONS & RECOMMENDATIONS

Like similar studies, there a number of limitations that were encountered in this study. The main limitation is that the global OLS model, and to some extent the local GWR model, are potential misspecified. This is based on the statistically significant Moran's *I* values for spatial autocorrelation for the residuals of both models. The OLS model exhibited positive spatial autocorrelation, which is problematic and usually means a key variable is missing from the analysis. However, without the required data or the knowledge of what the key variable is, it is very difficult to address model misspecification. Local modelling, such as the use of GWR, is suggested to address spatial autocorrelation if the misspecification may be a result of trying to model nosnstationary variables using a global model. In this study the GWR model did drastically reduce spatial autocorrelation of residuals, but it was still statistically significant. Meaning further steps would have had to be taken to identify some other additional spatial processes in the data (variables). This also means that the GWR model should be used as a complement to and not a replacement of the OLS model, and results should be interpreted with caution. Cho, Bowker & Park (2006) included a median housing value variable at "census-block group" level in their analysis to address spatial autocorrelation in the global model, which could be used for future hedonic studies concerning the Cape Town area.

Although, not explicitly evident in this study, the issue of multicollinearity should be kept in mind. The OLS model offered a means to identify multicollinearity using VIF values, but the spgwr package does not offer way to identify local multicollinearity. This problematic because if there is evidence of local multicollinearity, the derived interpretation of results can be misleading (Wheeler and Tiefelsdorf, 2005). It is suggested to use software that either identifies or that allows one to identify local multicollinearity, for GWR analysis.

Some examples of extreme coefficients were also identified in the results. Some of the local coefficients for describing the impact of recreational areas on property value were extremely high and extremely low, compared to the rest of the coefficients. These were subsequently removed for interpretation of the results. According to Cho et al. (2009a), extreme coefficients are more likely to be derived from polygon data representing aggregated values, which is the case in this study. However, the fact it was only a few features exhibiting extreme coefficients, and only in one of the three open space variables, the issue of extreme coefficients was not considered a major issue.

In general, using aggregated data results in the spatial details of a finer scale to be lost. Future studies could look at performing hedonic analysis at property level. In this study, two of the open space variables were constructed based on percentage of area within small areas (and adjacent small areas), to account for aggregation to SAL level. Assessing at a finer scale and keeping factors such as open space use, safety and crime, could give a better understanding on what is occurring in reality, and would give more of a contextual analysis of areas being assessed. Most studies use a distance based variable for all open spaces. It is suggested that at least a distance-based variable could also be used for assessing the relationship between open space and property value.

5.3. POLICY IMPLICATIONS

Based on the policy and planning documents compiled by the City of Cape Town municipality, it is evident that open space planning needs to be and has been considered in the whole planning system. Essentially, this is to preserve natural open space, but also to provide recreational opportunities for urban residents. This study shows that the relationship between open space types and property value cannot be generalised for the whole metropolitan area, which means analysis should be undertaken at a local level. By looking at the local effects of open space on property value, open space provision can be further planned in terms of local community needs. A study such as this can be conducted at district level and can be included in each of the district plans, to identify further details of spatial variation at a smaller scale. This would be useful, since local analysis indicates that for different areas there must be different methods of providing and managing open space.

Providing open space in terms of other variables, such as household income and population density, can give an indication of the type of areas that exhibit similar impacts on property values, based on access to open space. For example, areas that indicate a negative impact on property value by access to open space and which exhibit lower income, with higher densities, could be identified and prioritised for the provision and maintenance of quality open spaces, based on the local community needs. This could rejuvenate some communities socially and economically, and could aid in bridging the class gap between neighbourhoods.

The city can also then target existing open spaces that are ‘unsavoury’ or potentially dangerous, and implement ways to curb these negative aspects, through innovative design and proper management. Proper design and planning of where to include new recreational open space types, could also prevent new open spaces from becoming unsafe. Local modelling could help identify the already existing unsafe open spaces, and planners can determine the locational aspects that contribute to the negative characteristics of these open spaces. In identifying open spaces that negatively affect property value, planners can also focus on providing other types of open spaces that would be more appropriate within different communities.

Finally, this study indicates that the local analysis can provide local spatial patterns otherwise missed by global analysis. This study contributes to the existing research on hedonic analysis, and adds to the research that specifically looks at the application of GWR as a method to perform hedonic analysis.

(23742 words)

REFERENCES

Acharya, G., & Bennett, L. L. (2001). Valuing open space and land-use patterns in urban watersheds. *The Journal of Real Estate Finance and Economics*, *22*(2), 221-237.

Anderson, S. T., & West, S. E. (2006). Open space, residential property values, and spatial context. *Regional Science and Urban Economics*, *36*(6), 773-789.

Beale, C. M., Lennon, J. J., Yearsley, J. M., Brewer, M. J., & Elston, D. A. (2010). Regression analysis of spatial data. *Ecology letters*, *13*(2), 246-264.

Bolitzer, B., & Netusil, N. R. (2000). The impact of open spaces on property values in Portland, Oregon. *Journal of environmental management*, *59*(3), 185-193.

Boon, R. (2017, June). The edge update corner: Key information and plans in the city. *Economic Development and Growth in eThekwini* (16), 60. Retrieved 21 October 2017, from http://www.myvirtualpaper.com/doc/brochures/edge-16th-edition-manufacturing/2016070401/60.html.

Bowman, T., Thompson, J., & Colletti, J. (2009). Valuation of open space and conservation features in residential subdivisions. *Journal of Environmental Management*, *90*(1), 321-330.

Brander, L. M., & Koetse, M. J. (2011). The value of urban open space: Meta-analyses of contingent valuation and hedonic pricing results. *Journal of environmental management*, *92*(10), 2763-2773.

Brunsdon, C., Fotheringham, A. S., & Charlton, M. (1996). Geographically weighted regression: A method for exploring spatial nonstationarity. *Geographical analysis*, *28*(4), 281-298.

Brunsdon, C., Fotheringham, A. S., & Charlton, M. (1998). Geographically weighted regression. *Journal of the Royal Statistical Society: Series D (The Statistician)*, *47*(3), 431-443.

Brunsdon, C., Fotheringham, A. S., & Charlton, M. (1999). Some notes on parametric significance tests for geographically weighted regression. *Journal of Regional science*, *39*(3), 497-524.

Charlton, M., & Fotheringham, A. S., (2009a). Geographically weighted regression: a tutorial on using GWR in ArcGIS 9.3. National Centre for Geocomputation. National University of Ireland.

Charlton, M., & Fotheringham, A. S., (2009b). *Geographically Weighted Regression White Paper*. The University of Edinburgh.

Cho, S. H., Bowker, J. M., & Park, W. M. (2006). Measuring the contribution of water and green space amenities to housing values: An application and comparison of spatially weighted hedonic models. *Journal of agricultural and resource economics*, 485-507.

Cho, S., & Roberts, R.K. (2007). Cure for urban sprawl: Measuring the ratio of marginal implicit prices of density-to-lot-size. *Review of Agricultural Economics* 29, 572–579.

Cho, S. H., Poudyal, N. C., & Roberts, R. K. (2008). Spatial analysis of the amenity value of green open space. *Ecological Economics*, 66(2), 403-416.

Cho, S., Lambert, D. M., Kim, S. G., & Jung, S. (2009a). Extreme coefficients in geographically weighted regression and their effects on mapping. *GIScience & Remote Sensing*, *46*(3), 273-288.

Cho, S. H., Clark, C. D., Park, W. M., & Kim, S. G. (2009b). Spatial and temporal variation in the housing market values of lot size and open space. *Land Economics*, *85*(1), 51-73.

Cilliers, J., & Cilliers, S. (2015). From green to gold: A South African example of valuing urban green spaces in some residential areas in Potchefstroom. *Stads-en Streeksbeplanning= Town and Regional Planning*, *2015*(67), 1-12.

City of Cape Town. (2002). *State of environment report for the City of Cape Town year 5*. Retrieved 21 October 2017, from http://soer.deat.gov.za/dm_documents/City_of_Cape_Town_Yr_5_full_report_f68Zu.pdf.

City of Cape Town. (2008). *Integrated metropolitan environmental policy*. Retrieved 21 October 2017, from http://resource.capetown.gov.za/documentcentre/Documents/Bylaws%20and%20policies/Integrated%20Metropolitan%20Environmental%20Policy%20(IMEP)%20-%20English%20-%20approved%20on%2025%20June%202008.pdf.

City of Cape Town. (2012a). *Cape Town spatial development framework: Statutory report*. Retrieved 21 October 2017, from http://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/SDF_Technical_Report_2012_Interactive.pdf.

City of Cape Town. (2012b). *Tygerberg district plan*. Spatial development plan and environmental management framework: Technical report. Retrieved 21 October 2017, from http://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/Tygerberg_District_Plan_Technical_Report.pdf.

City of Cape Town. (2015a). *Policy: Parks development.* Retrieved 21 October 2017, from http://resource.capetown.gov.za/documentcentre/Documents/Bylaws%20and%20policies/Parks%20Development%20Policy%20-%20(Policy%20number%2037181)%20approved%20on%2028%20January%202015.pdf.

City of Cape Town. (2015b). Policy: The Cape Town bioregional plan. Retrieved 21 October 2017, from http://resource.capetown.gov.za/documentcentre/Documents/Bylaws%20and%20policies/Bioregional_Plan_CCT_FINAL_2015-08-19_policy_number_44854.pdf.

City of Cape Town. (2016a). *Cape Town spatial development framework: Map 6.1*. Retrieved 21 October 2017, from http://resource.capetown.gov.za/documentcentre/Documents/Maps%20and%20statistics/Cape%20Town%20SDF_May2016.pdf.

City of Cape Town. (2016b). *Policy: Sport and recreational policy framework*. Retrieved 21 October 2017, from http://resource.capetown.gov.za/documentcentre/Documents/Bylaws%20and%20polici es/Sport%20and%20Recreation%20Policy%20Framework%202015%20-%20(Policy%20number%2043752)%20approved%20on%2028%20January%202016.pdf.

City of Cape Town: Public Parks By-law, 2010.

City of Cape Town Municipal Planning By-Law, 2015.

City of Tshwane. (2005). *Proposed Tshwane open space framework, Volume 1: Status quo.* Retrieved 16 October 2017, from http://www.tshwane.gov.za/sites/residents/Services/OpenSpaceManagement/Framework/Open%20Space%20Framework%20Vol%201.pdf.

City of Tshwane. (2005). *Proposed Tshwane open space framework, Volume 2: Open space plan.* Retrieved 16 October 2017, from http://www.tshwane.gov.za/sites/residents/Services/OpenSpaceManagement/Framework/Open%20Space%20Framework%20Vol%202.pdf.

Constitution of the Republic of South Africa, Act no. 108 of 1996.

Conway, D., Li, C. Q., Wolch, J., Kahle, C., & Jerrett, M. (2010). A spatial autocorrelation approach for examining the effects of urban greenspace on residential property values. *The Journal of Real Estate Finance and Economics*, *41*(2), 150-169.

Correll, M. R., Lillydahl, J. H., & Singell, L. D. (1978). The effects of greenbelts on residential property values: Some findings on the political economy of open space. *Land economics*, *54*(2), 207-217.

Crompton, J. L. (2000). *The impact of parks and open space on property values and the property tax base*. Division of Professional Services, National Recreation & Park Association.

Crompton, J. L. (2005). The impact of parks on property values: Empirical evidence from the past two decades in the United States. *Managing Leisure*, *10*(4), 203-218.

Crouch D. P. (1981). The Historical Development of Urban Open Space: We reflect our urban landscapes. In Taylor, L. (Ed.), *Urban open spaces* (pp. 4-6). London: Academy Editions.

CSIR Building and Construction Technology (2000). *Guidelines for human settlement planning and design: Volume 1*. Pretoria: CSIR.

ESRI (2016a). *Interpreting GWR results*. ArcGIS Desktop Help: Release 10.4.1. Redlands, CA: Environmental Systems Research Institute.

ESRI (2016b). *Interpreting OLS results*. ArcGIS Desktop Help: Release 10.4.1. Redlands, CA: Environmental Systems Research Institute.

ESRI (2016c). *How Spatial Autocorrelation (Global Moran's I) works*. ArcGIS Desktop Help: Release 10.4.1. Redlands, CA: Environmental Systems Research Institute.

ESRI (2016d). *Ordinary Least Squares (OLS) (Spatial Statistics)*. ArcGIS Desktop Help: Release 10.4.1. Redlands, CA: Environmental Systems Research Institute.

Farber, S., & Páez, A. (2007). A systematic investigation of cross-validation in GWR model estimation: Empirical analysis and Monte Carlo simulations. *Journal of Geographical Systems*, *9*(4), 371-396.

Florida Recreation Parks Association. (1975). *Criteria for leisure facilities: Florida design standards and quantities for parks, recreation and open space*. Tallahassee, Fla.: Florida Recreation and Parks Association.

Fotheringham, A. S., Charlton, M., & Brunsdon, C. (1998). Geographically weighted regression: A natural evolution of the expansion method for spatial data analysis. *Environment and planning A*, *30*(11), 1905-1927.

Fotheringham, A. S., Brunsdon, C., & Charlton, M. (2002). *Geographically weighted regression*. John Wiley & Sons, Limited.

Francis, M. (1987). Urban open spaces. In Zube, E. H., & Moore, G. T. (Eds.), *Advances in environment, behavior, and design: Volume 1* (pp. 71-106). Plenum Press.

Geoghegan, J., Wainger, L. A., & Bockstael, N. E. (1997). Spatial landscape indices in a hedonic framework: an ecological economics analysis using GIS. *Ecological economics*, *23*(3), 251-264.

Geoghegan, J. (2002). The value of open spaces in residential land use. *Land use policy*, *19*(1), 91-98.

Geoghegan, J., Lynch, L., & Bucholtz, S. (2003). Capitalization of open spaces into housing values and the residential property tax revenue impacts of agricultural easement programs. *Agricultural and Resource Economics Review*, *32*(1), 33-45.

Geographically Weighted Modelling. (2017). *GWR in ArcGIS*. Retrieved 4 October 2017, from http://gwr.maynoothuniversity.ie/gwr-in-arcgis/.

Green, C., & Argue, T. (2012). *CSIR Guidelines for the provision of social facilities in South African settlements*. CSIR Built Environment.

Gupta, V., Mythili, G., & Hegde, D. S. (2009). Deriving implicit prices for urban environmental amenities from Mumbai housing prices: a revealed preference approach. In *First International Conference on Landscape Economics, Vienna*.

Halprin, L. (1981). The Collective Perception of Cities: We reflect our urban landscapes. In Taylor, L. (Ed.), *Urban open spaces* (pp. 4-6). London: Academy Editions.

Hicks, R. L., & Queen, B. M. (2016). Valuing Historical and Open Space Amenities with Hedonic Property Valuation Models. *Agricultural and Resource Economics Review*, *45*(1), 44-67.

Huang, B., Wu, B., & Barry, M. (2010). Geographically and temporally weighted regression for modeling spatio-temporal variation in house prices. *International Journal of Geographical Information Science, 24*(3), 383-401.

Hui, E. C., Chau, C. K., Pun, L., & Law, M. Y. (2007). Measuring the neighboring and environmental effects on residential property value: Using spatial weighting matrix. *Building and environment*, 42(6), 2333-2343.

Irwin, E. G., & Bockstael, N. E. (2001). The problem of identifying land use spillovers: Measuring the effects of open space on residential property values. *American journal of agricultural economics*, *83*(3), 698-704.

Irwin, E.G. (2002). The effects of open space on residential property values. *Land economics*, *78*(4), pp.465-480.

Koomen, E., Dekkers, J., Koetse, M., Rietveld, P., & Scholten, H. (2005). *Valuation of metropolitan open space-presenting the research framework*. Paper presented at 45th congress of the European Regional Science Association August 23 –27, 2005 Amsterdam, Netherlands.

Lambert, A. (2003). Economic valuation of wetlands: An important component of wetland management strategies at the river basin scale. *Conservation Finance Guide, Washington*.

Landman, K., & Du Toit, J. (2014). Residents' perceptions of the importance of outdoor spaces and neighbourliness for medium-density mixed-housing in South Africa. *Town and Regional Planning*, *65*(1), 23-34.

LeSage, J. P. (1997). Regression analysis of spatial data. *Journal of Regional Analysis and Policy*, *27*, 83-94.

LeSage, J. P. (2001). A family of geographically weighted regression models. In Anselin, L., Florax, R. J. G. M., & Rey, S. J. (Eds.) *Advances in spatial econometrics* (pp. 241-264). Springer Berlin Heidelberg.

Leung, Y., Mei, C. L., & Zhang, W. X. (2000). Testing for spatial autocorrelation among the residuals of the geographically weighted regression. *Environment and Planning A*, *32*(5), 871-890.

Lewis, L. Y., Bohlen, C., & Wilson, S. (2008). Dams, dam removal, and river restoration: A hedonic property value analysis. *Contemporary Economic Policy*, *26*(2), 175-186.

Lindsey, G., Man, J., Payton, S., & Dickson, K. (2004). Property values, recreation values, and urban greenways. *Journal of Park and Recreation Administration*, *22*(3), 69-90.

Little, C. E. (1969). *Challenge of the Land*. Pergamon.

Local Government: Municipal Systems, Act no. 32 of 2000.

Lubbe, C. S. (2011). Comparison of the urban domestic garden flora along a socio–economic gradient in the Tlokwe City Municipality. Doctoral dissertation, North-West University, Potchefstroom.

Luttik, J. (2000). The value of trees, water and open space as reflected by house prices in the Netherlands. *Landscape and urban planning*, *48*(3), 161-167.

Lutzenhiser, M., & Netusil, N. R. (2001). The effect of open spaces on a home's sale price. *Contemporary Economic Policy*, *19*(3), 291-298.

Marlene Laros & Associates. (2007). *City of Cape Town: The identification and prioritisation of a biodiversity network for the City of Cape Town*. Retrieved 21 October 2017 from, http://resource.capetown.gov.za/documentcentre/Documents/City%20research%20reports%20and%20review/BioDNet_Final_Report_02_2007_19122007172753_465.pdf.

Mashalaba, Y. B. (2013). Public open space planning and development in previously neglected townships. Doctoral dissertation, University of Free State, Bloemfontein.

Maswime, T. A. M., 2006. The contribution of estuaries to residential property values in the Cape Floristic Region, South Africa. Dissertation, University of Cape Town, Cape Town.

McConnell, V., & Walls, M. A. (2005). *The value of open space: Evidence from studies of nonmarket benefits*. Washington, DC: Resources for the Future.

Meese, R., & Wallace, N. (1991). Nonparametric estimation of dynamic hedonic price models and the construction of residential housing price indices. *Real Estate Economics*, *19*(3), 308-332.

National Environmental Management, Act no. 107 of 1998.

Nembudani, M. E. (1997). Geographical analysis of public open spaces for recreational use in Guguletu, Cape Town.

Netusil, N. R. (2005). The effect of environmental zoning and amenities on property values: Portland, Oregon. *Land Economics*, *81*(2), 227-246.

Nicholls, S., & Crompton, J. L. (2005). The impact of greenways on property values: Evidence from Austin, Texas. *Journal of Leisure Research*, *37*(3), 321.

Pavlov, A. D. (2000). Space-varying regression coefficients: A semi-parametric approach applied to real estate markets. *Real Estate Economics*, *28*(2), 249-283.

Pearson, L. J., Tisdell, C., & Lisle, A. T. (2002). The impact of Noosa National Park on surrounding property values: An application of the hedonic price method. *Economic Analysis and Policy*, *32*(2), 155-171.

Rogerson, P. (2001). *Statistical methods for geography*. Sage.

Rosen, S. (1974). Hedonic prices and implicit markets: Product differentiation in pure competition. *Journal of political economy*, *82*(1), 34-55.

Saphores, J. D., & Li, W. (2012). Estimating the value of urban green areas: A hedonic pricing analysis of the single family housing market in Los Angeles, CA. *Landscape and Urban Planning*, *104*(3), 373-387.

Sirmans, S., Macpherson, D., & Zietz, E. (2005). The composition of hedonic pricing models. *Journal of real estate literature*, *13*(1), 1-44.

Spatial Planning and Land Use Management, Act no. 16 of 2013.

Standiford, R. B., & Scott, T. (2001). Value of oak woodlands and open space on private property values in Southern California. *Forest Systems*, *10*(3), 137-152.

Statistics South Africa. (n.d.). Census Definitions. Apps.statssa.gov.za. Retrieved 5 October 2017, from https://apps.statssa.gov.za/census01/Census96/HTML/Metadata/Docs/Dfntns.html.

Statistics South Africa. (2017). Small area statistics. Statssa.gov.za. Retrieved 5 October 2017, from http://www.statssa.gov.za/?page_id=4086.

Strategic Environmental Focus. (2002). *Joburg metropolitan open space system*. Retrieved 21 October 2017, from https://joburg.org.za/docs/jmossreport.doc.

Tobler, W. R. (1970). A computer movie simulating urban growth in the Detroit region. *Economic geography*, *46*(sup1), 234-240.

Troy, A., & Grove, J. M. (2008). Property values, parks, and crime: A hedonic analysis in Baltimore, MD. *Landscape and urban planning*, *87*(3), 233-245.

Tse, R. Y., & Love, P. E. (2000). Measuring residential property values in Hong Kong. *Property Management*, *18*(5), 366-374.

Tyrväinen, L. (1997). The amenity value of the urban forest: An application of the hedonic pricing method. *Landscape and Urban planning*, *37*(3-4), 211-222.

United Nations, General Assembly. (2016). *Draft outcome document of the United Nations Conference on Housing and Sustainable Urban Development (Habitat III),* A/CONF.226/4. Retrieved 20 July 2017 from https://www2.habitat3.org/bitcache/99d99fbd0824de50214e99f864459d8081a9be00?vid=591155&disposition=inline&op=view.

Van Wyk, J. (2012). *Planning law* (2nd ed., Juta's property law library). Claremont: Juta.

Wheeler, D., & Tiefelsdorf, M. (2005). Multicollinearity and correlation among local regression coefficients in geographically weighted regression. *Journal of Geographical Systems*, *7*(2), 161-187.

Wheeler, D. C. (2007). Diagnostic tools and a remedial method for collinearity in geographically weighted regression. *Environment and Planning A*, *39*(10), 2464-2481.

Wheeler, D.C., & Páez, A. (2009). Geographically Weighted Regression. In Fischer, M. M., & Getis, A. (Eds.), *Handbook of applied spatial analysis: Software tools, methods and applications* (pp. 461-486). Springer Science & Business Media.

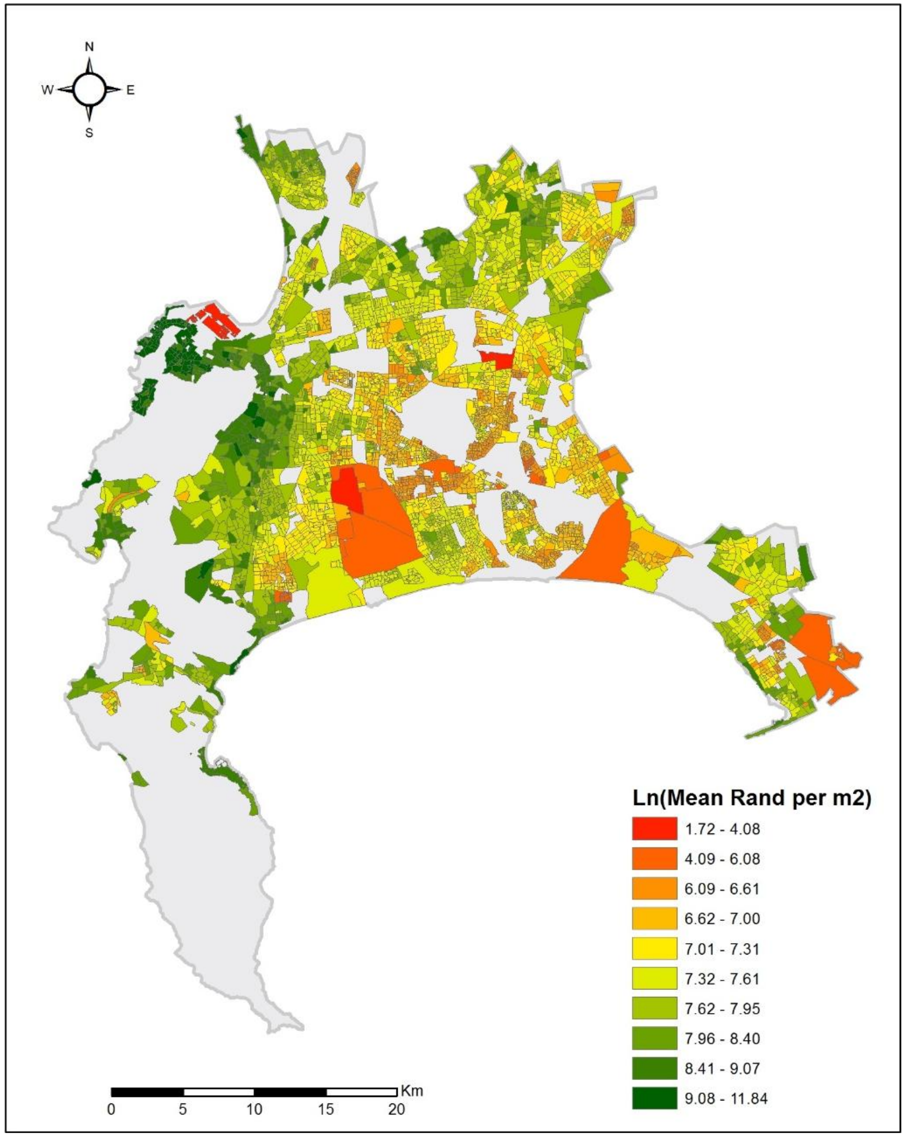
Willemse, L. (2013). A Flowmap–geographic information systems approach to determine community neighbourhood park proximity in Cape Town. *South African Geographical Journal*, *95*(2), 149-164.

Willemse, L. (2015). Some perceptions and preferences of residents' use of community neighbourhood parks in Mitchells Plain, Cape Town. *Town and Regional Planning*, *66*(1), 15-30.

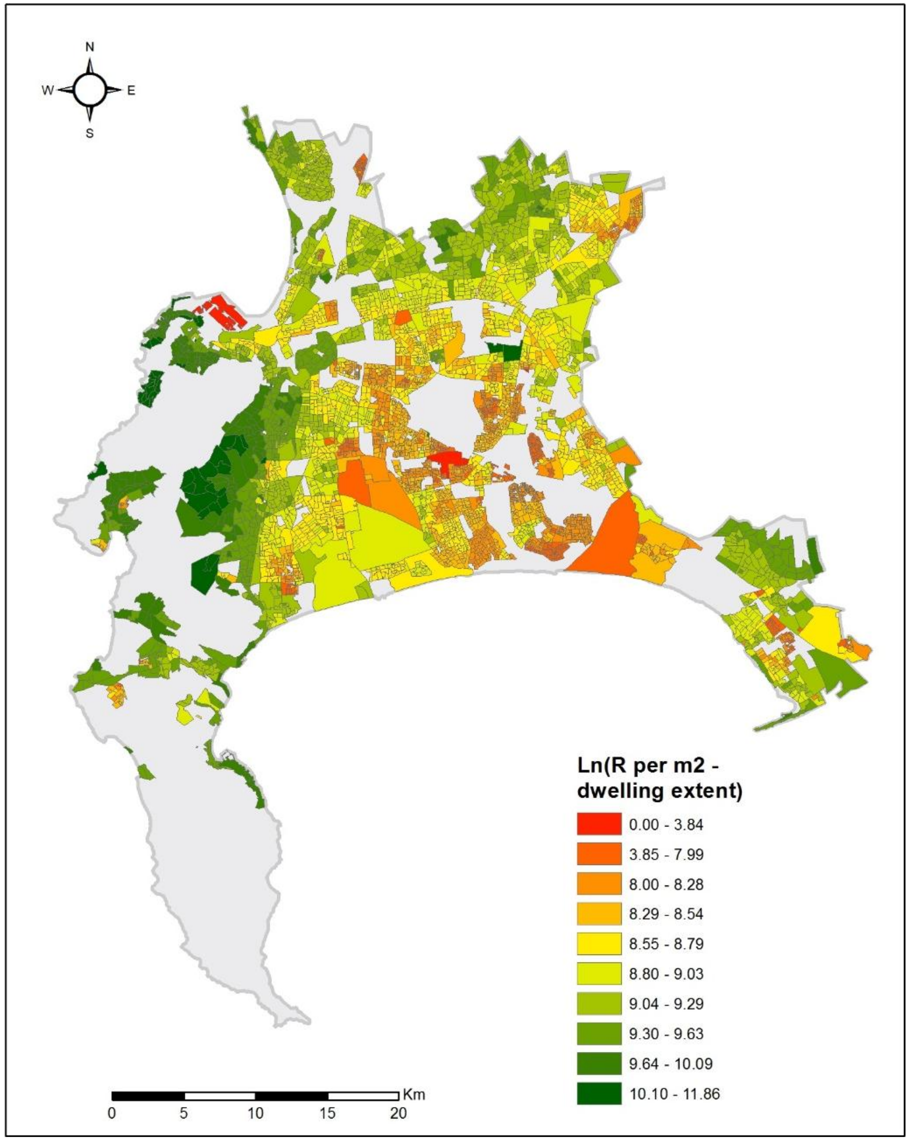
Woolley, H. (2003). *Urban open spaces*. Taylor & Francis.

Yu, D. L. (2006). Spatially varying development mechanisms in the Greater Beijing Area: A geographically weighted regression investigation. *The Annals of Regional Science*, *40*(1), 173-190.

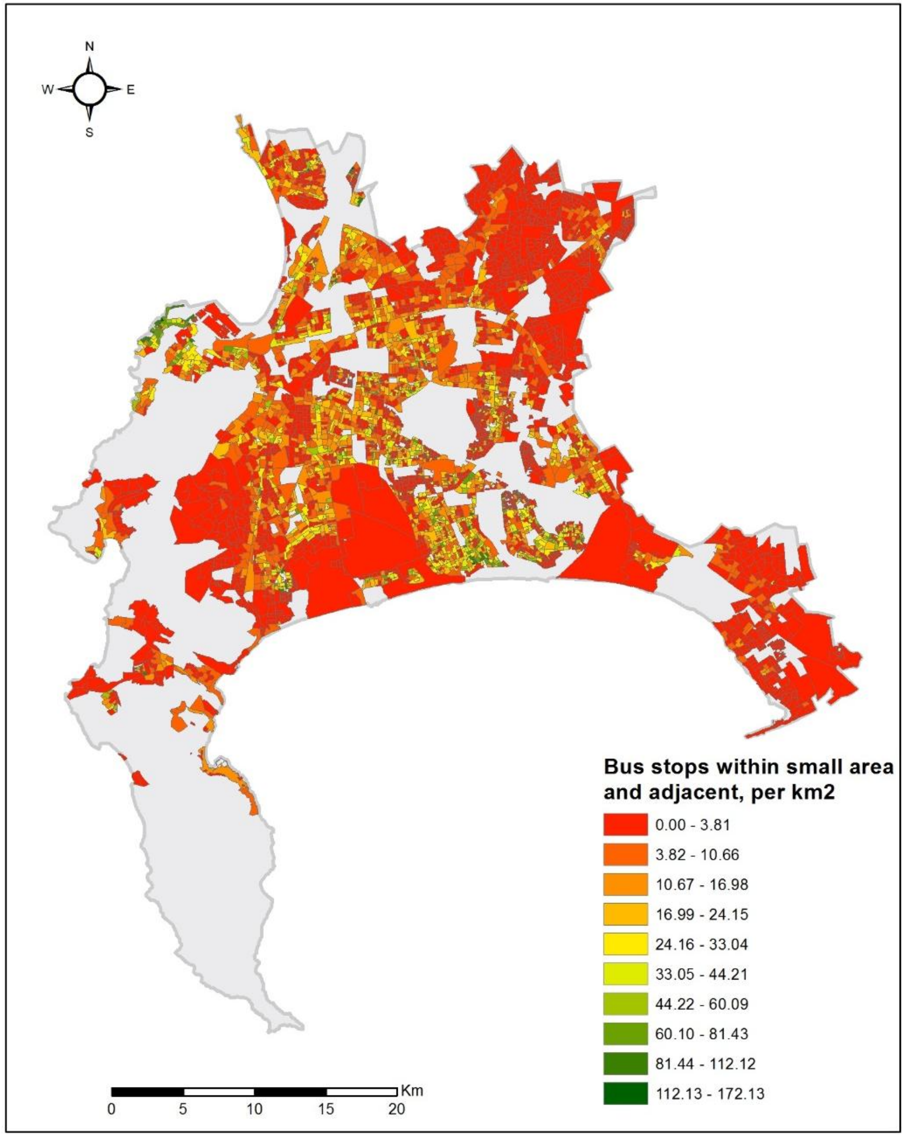
APPENDIX A: VARIABLES FOR HEDONIC ANALYSIS



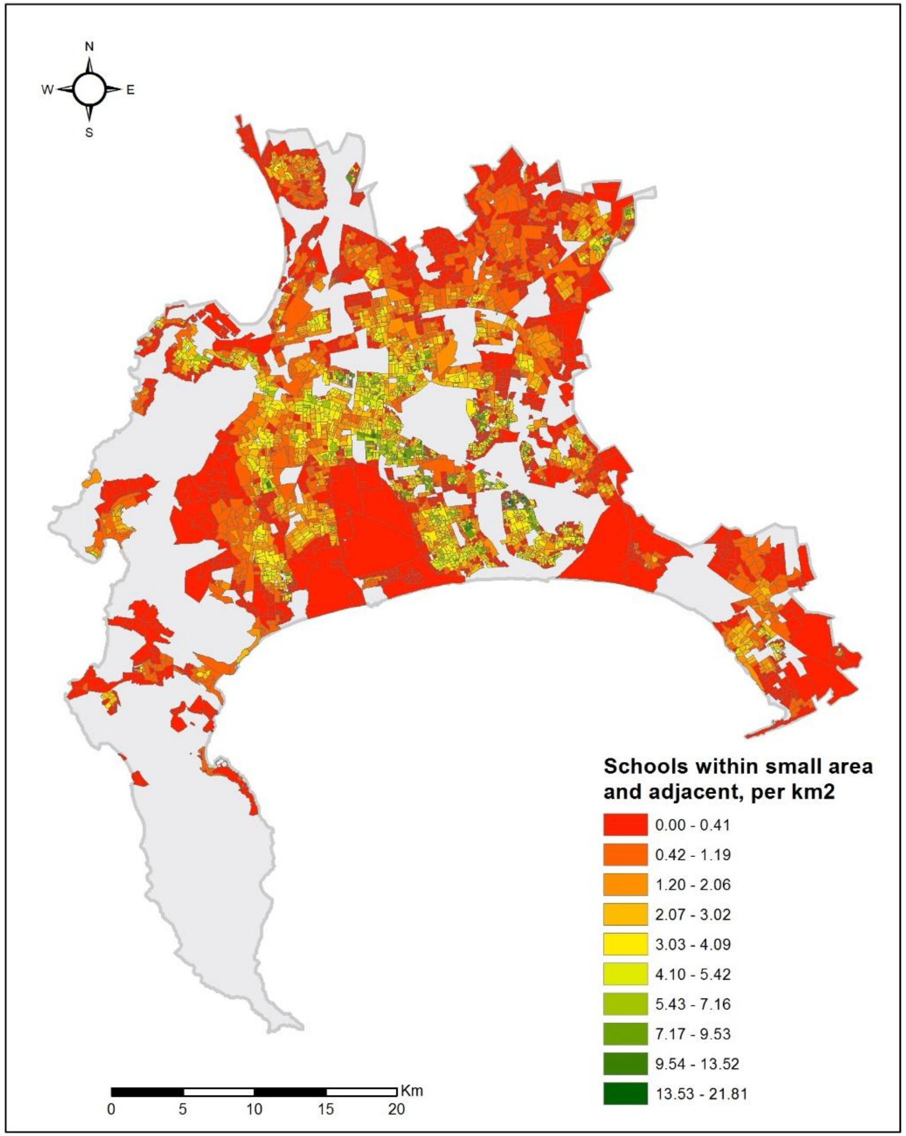
Ln_Rm2



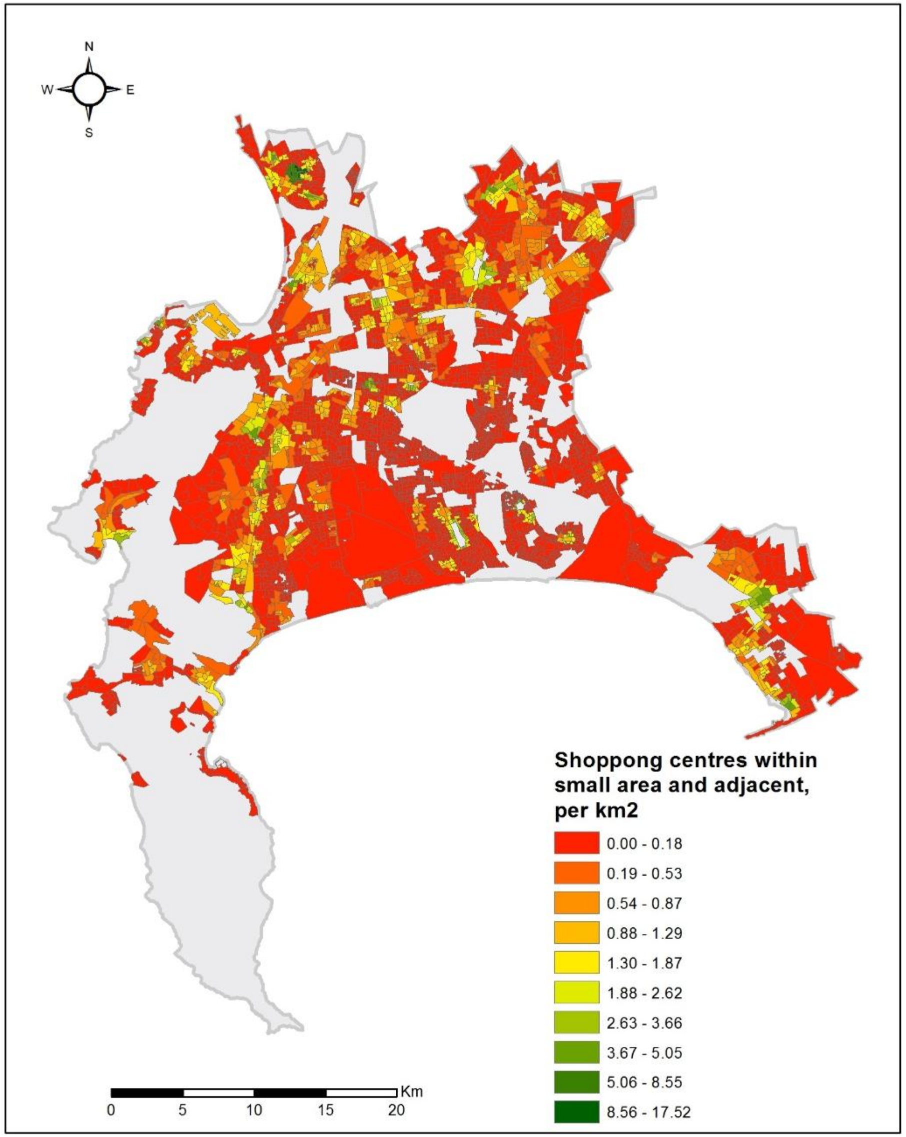
Ln_Rm2dext



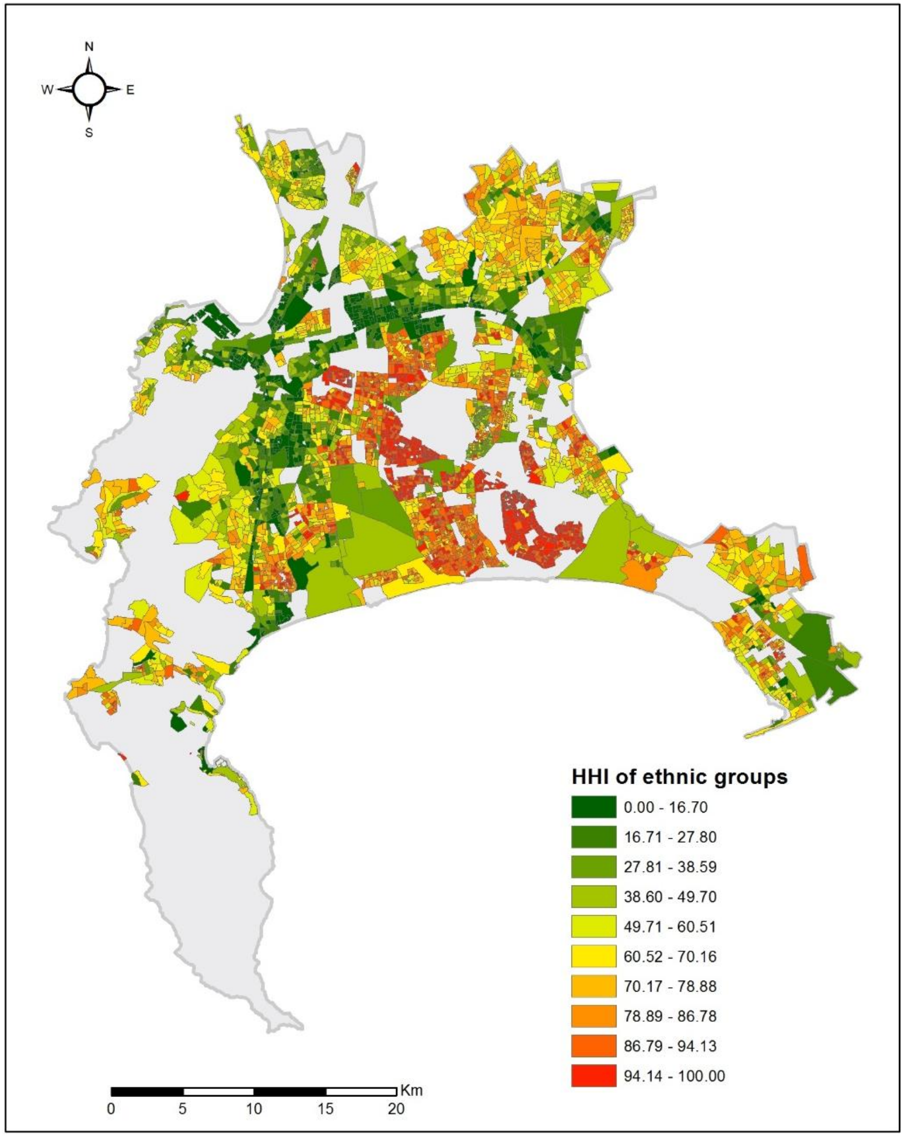
Bus_km2



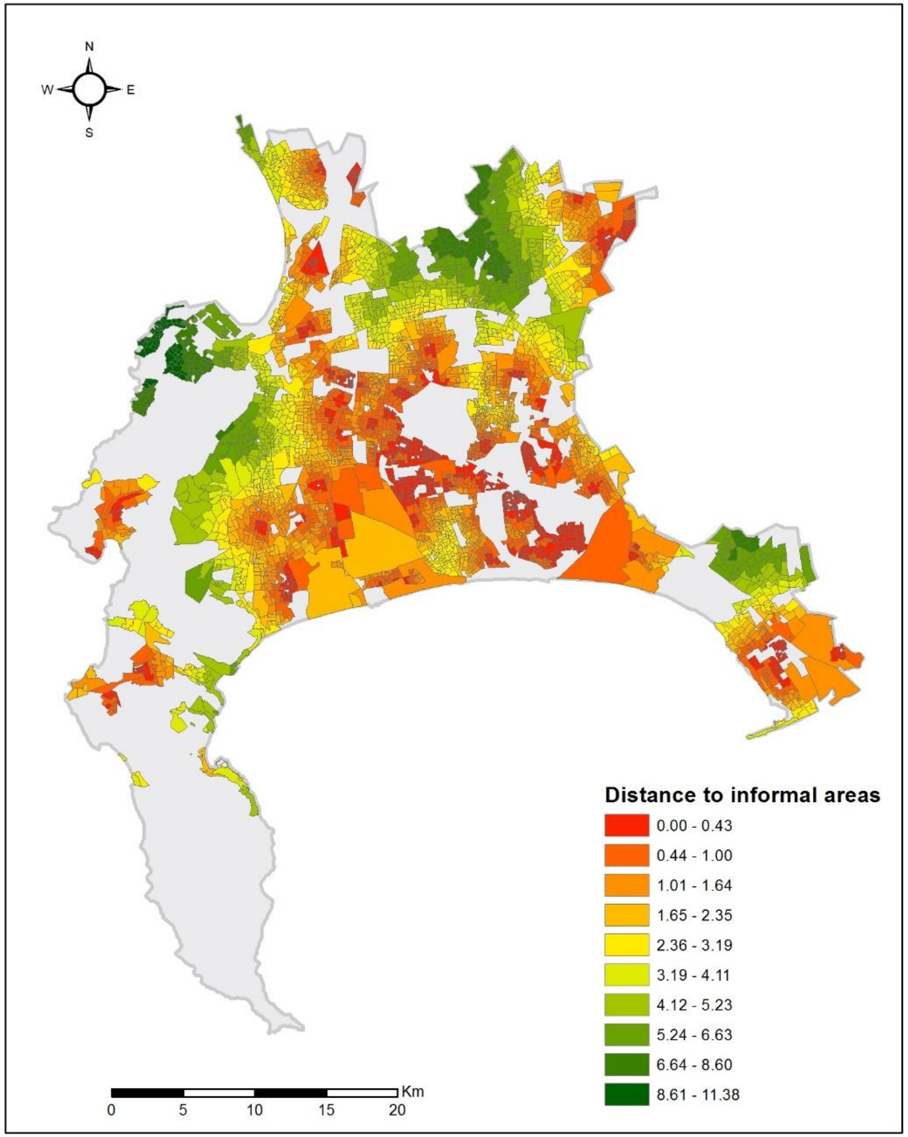
Schlwa_km2



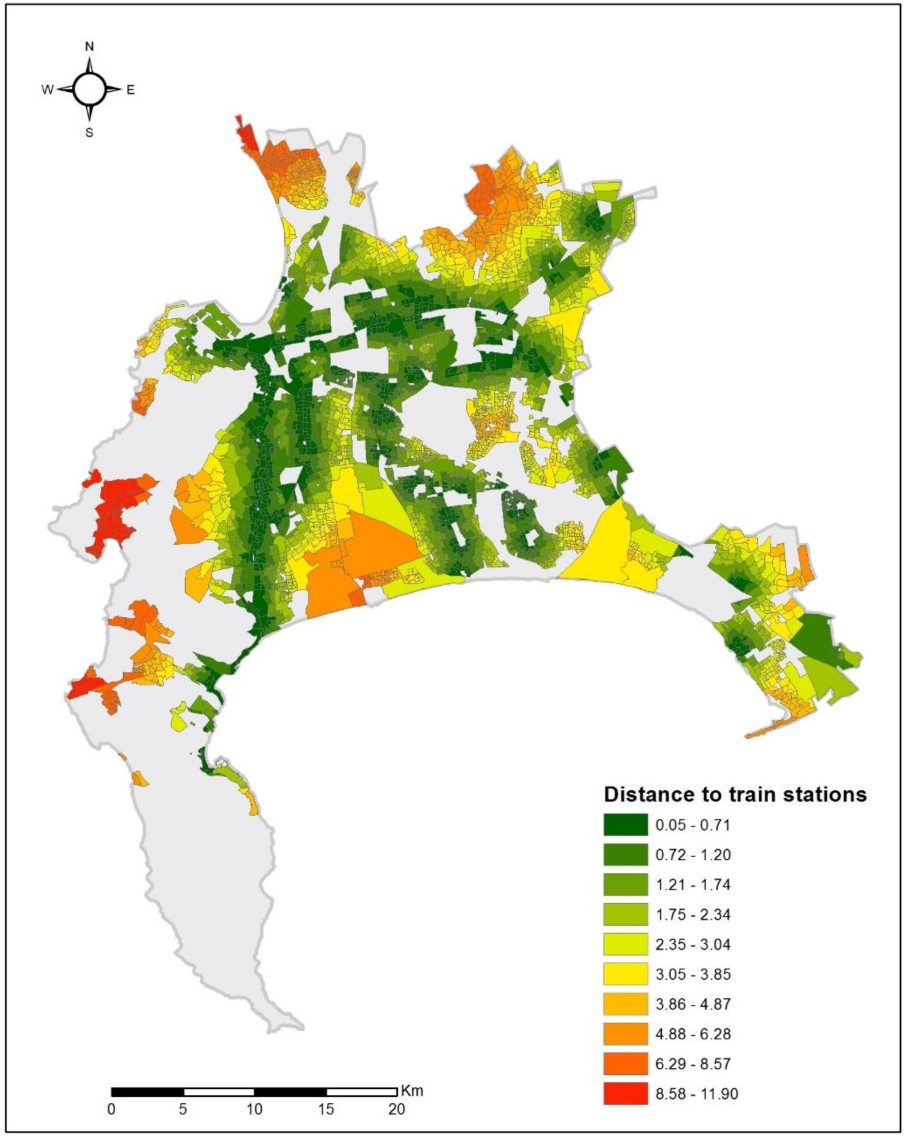
Shopwa_km2



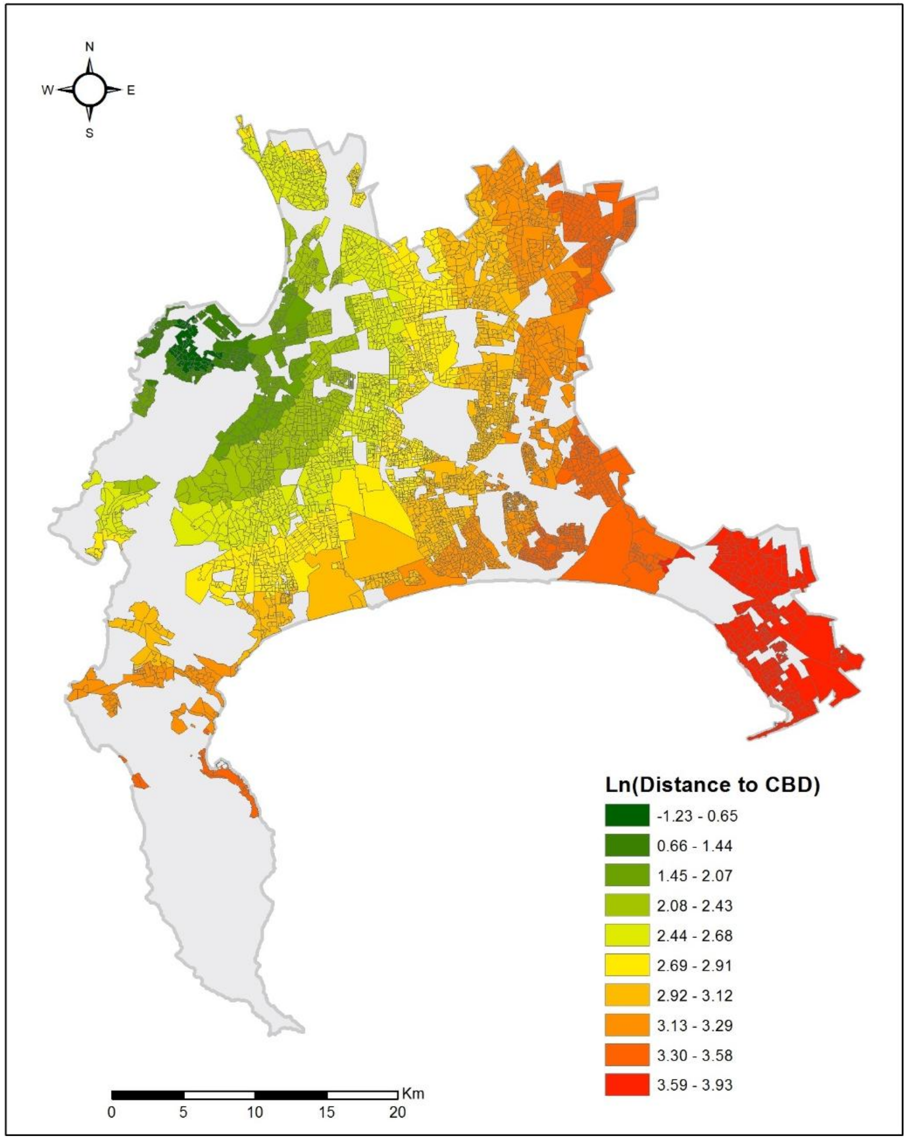
HHI



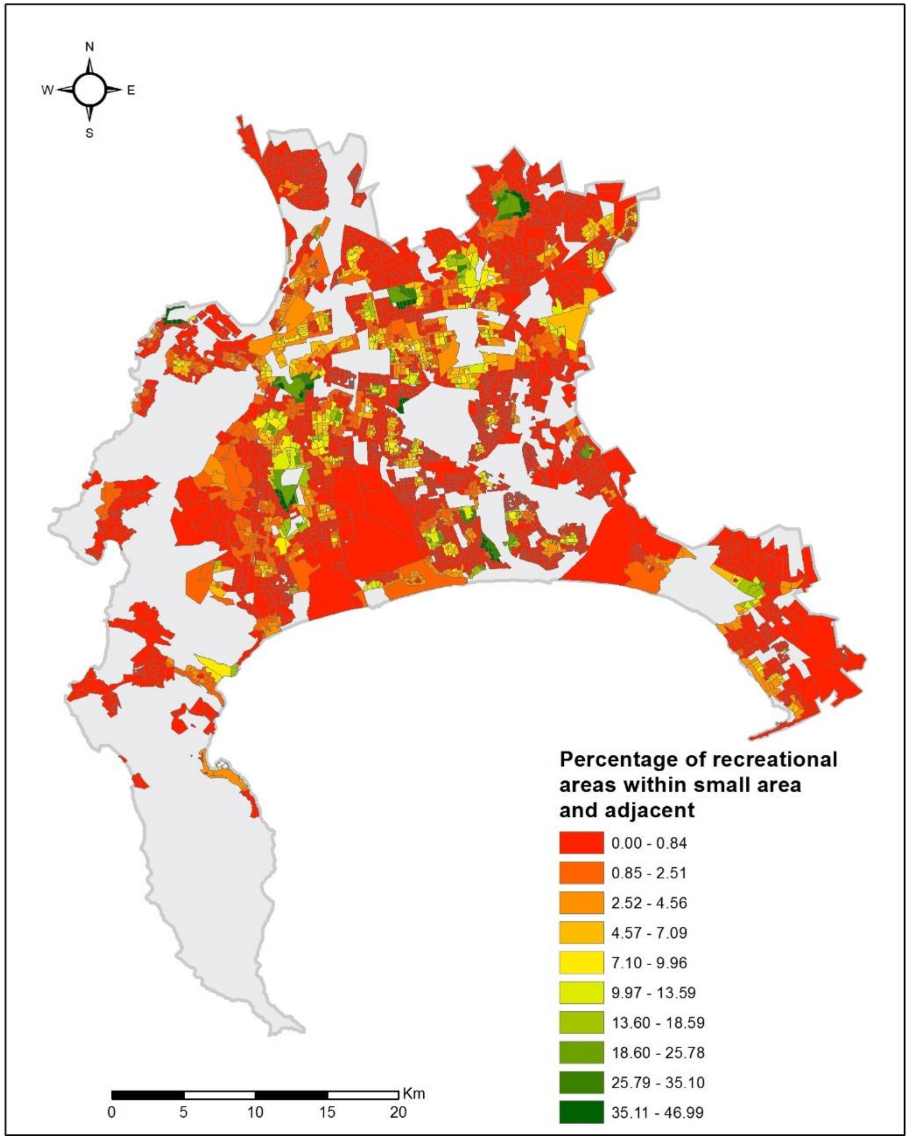
Dist2Infor



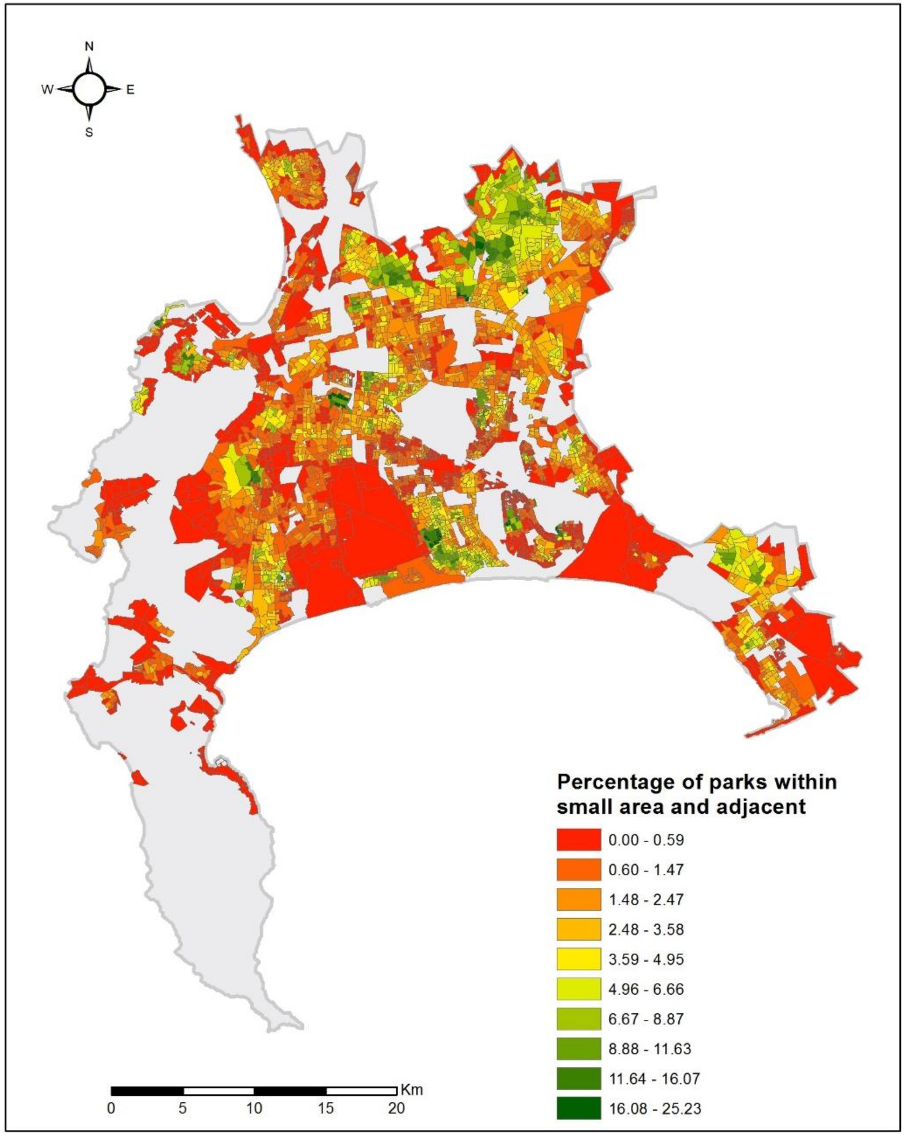
Dist2Train



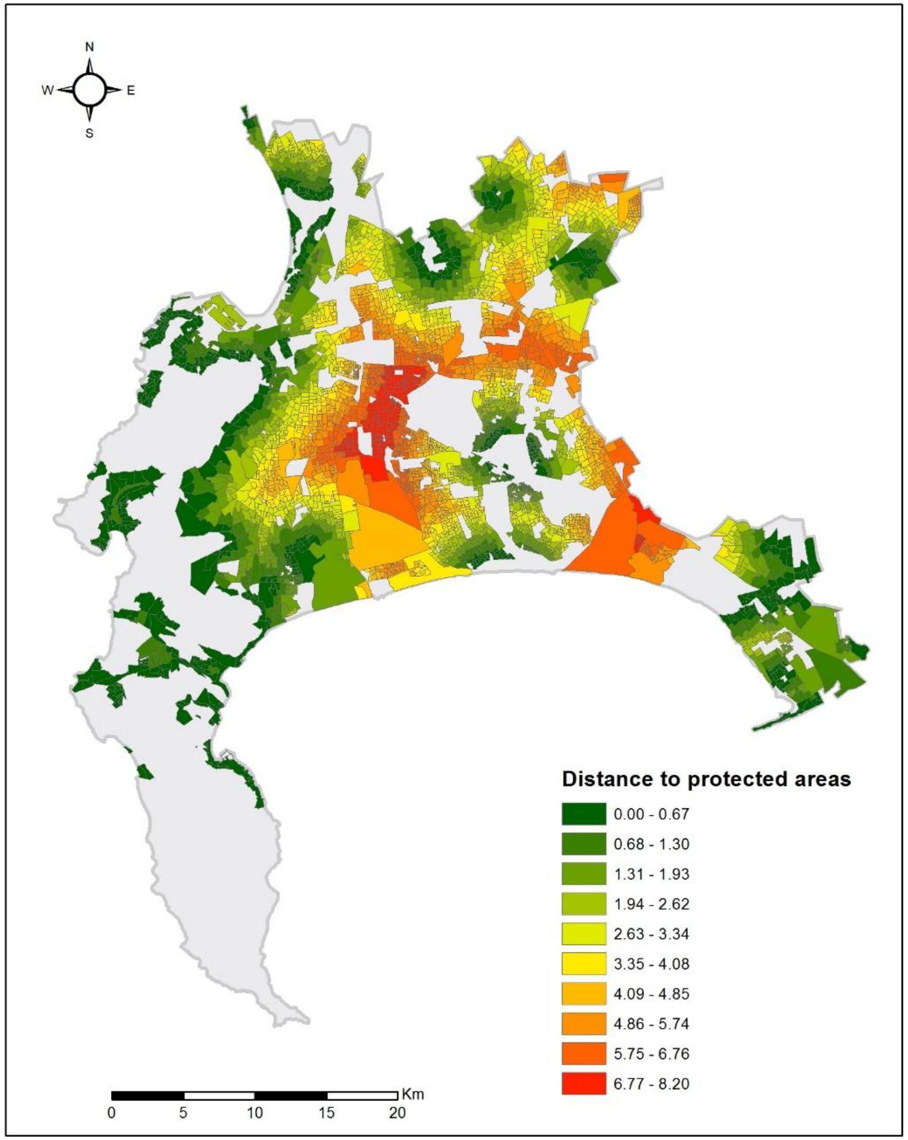
Ln_CBD



Recwa_perc



Parkwa_pe



Dist2PA